Assessment of Application of Life Cycle Cost on Construction Projects

by

Sami A. Al-Busaad

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

October, 1997

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This thesis, written by SAMI A. BU-SAAD under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING & MANAGEMENT.**

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DEDICATION

I dedicate this work to my parents,

my wife and my children whose

patience, prayers and perseverance

led to this accomplishment.

ACKNOWLEDGMENT

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Also, I thank all government agencies and consulting firms, especially The Ministry of Municipal and Rural Affairs and The Ministry of Defense and Aviation (MODA) in Riyadh for their kind participation in the survey and their helpful comments.

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THESIS ABSTRACT

STUDENT NAME : **SAMI AHMAD KHALID AL-BUSAAD**

THESIS TITLE : **THE ASSESSMENT OF APPLICATION OF LIFE CYCLE COST ON PUBLIC CONSTRUCTION PROJECTS**

MAJOR : **CONSTRUCTION ENGINEERING AND MANAGEMENT**

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This research discusses life cycle costing (LCC) and the extent of its application in public construction projects. It studies frequency, extent and severity of problems in application. Twenty six (26) problems were identified and classified into five major groups.

A survey of 45 government agencies and 250 consulting firms was concluded through a structured questionnaire. The collected data was analyzed from the data-base. The severity index and the ranking of problems for each individual party was calculated providing the basis for the statistical measures.

The hypothesis that the two parties generally agree on the severity of ranking of the individual and group problems was tested. It was concluded that the government agencies disagree with the consulting firms in the severity ranking of problems.

The researcher concluded that most government agencies and several consulting firms are aware of LCC technique and apply them selectively. The frequency and extent of application is generally low, due to several problems, namely: management pressure to meet budget and design limits, unavailability of data resources and un-familiarization of LCC benefits. Some specialist firms, however, extensively apply the technique and are very knowledgeable about it. The study concludes that the infrastructure needs to be improved. Knowledgeable, competent consultants and staff are insufficient for the needs.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

DHAHRAN, SAUDI ARABIA

خلاصـــة الرســـالة

اســـم الطالب : ســـامي أحمد خـالد البوســعد

عنـوان الرسـالة : إدخال نظـام تكلفة دورة الحيـاة في تشيـد المشـاريع

التـــخصص : برنـامج هندســة وإدارة التشيـــد

تاريخ الشـهادة : أكتوبر ١٩٩٧م

تناقـش الرســالة نظـام تكلفـــة دورة الحيـــاة ومـدى تطبيقـه في المشـــاريع الإنشـــائية في المملكة العربية الســعودية. تدرس الرســالة مدى تكرار وتأثير عدد مـن الأسبـــاب التـــي تـؤدي إلى عدم تطبـيق النظام. لـقد حدد ستة وعشـرون (٢٦) ســبباً تـم تصنيفها في خمـس مجـموعـات.

لقـــد تم القيـــام بمســـح ميدانـــي مـــن خـلال استبيـــان شـــمل ٤٥ هيئـــة حكوميـــة و ٢٥٠مكتـب استشـارات بمختـلف منـاطق المملكة. وبناءا على ذلك تم عمـل تحليـل إحصائي لكافـة المعلومات بعد إ يجاد التكرار وحســاب مؤشـر التأثيـر وترتيب أسـباب عدم تطبـيق وذلك لكـــل طـرف على حـده.

كما تم اختبار فرضيـة أن كلا الطرفين متفقيـن بشـكل عام على ترتيـب تأثيـر أسـباب عدم التطبيق ، وقد استنـتج أن الهيئـات الحكومية غير متفقة مع الاستشاري على هذا الترتيب.

ولقـد خلـص البـحث إلى أن هنـاك كثيـر مـن الدوائـر الحكوميـة وعـدد مـن المكـاتب الاستشارية على دراية بنظام تكلفـة دورة الحياة ويتم تطبيقـه اختيارياً. كما خلصت الدراسـة إلى أن حجـم تطبيق النظام يعتبر متدنيـاً وذلك لعدة أسباب ,أهمها : الالتزام بميزانية ووقت محدد للمشروع, نـدرة مـوارد المعلومـات وقصـور المعرفـة بفوائـد النظـام. كمـا وجـد أن هنـاك عـدد مـن المكـاتب الاستشارية من يقوم بتطبيق النظـام بكفاءة عالية ولديهم معرفة بالمفهوم. و أكدت الرسـالة الحاجة إلى تطويـر البنية الأساسية للنظام وتطوير الموارد الحالية.

درجـة الماجستيـر في العلـوم

جامعـة الملـك فهـد للبتـرول والمعـادن

الظهـران، المملـكة العربيـة الســعودية

CHAPTER 1

1.1 INTRODUCTION

GENERAL

Buildings are considered an investment in the future. The buildings around the world demonstrate that returns on such investments will last for hundreds of years and this will not be achieved without continuing maintenance and operating of the facility. Failure to make effective building expenditures during the life cycle of the building can lead to premature deterioration or loss of services, damage to facilities and exposure of occupants to unsafe conditions.

Accordingly, designer selection of proper construction materials that can lower or eliminate replacement or repair during future maintenance and operation will help in lowering overall costs. Designers and owners of buildings often recognize that there are possibilities of trade-offs between initial costs and recurring costs. They are, also, aware that the decision about the building design, construction, operation and maintenance can be made in principle so that the building performs well over a specified time with minimum total costs (Coullahan, 1996).

1.2 THE CONSTRUCTION INDUSTRY IN SAUDI ARABIA

Saudi Arabia is a rich developing country where the construction industry represents one of the largest economic sectors. During the decade 1970-1980,

Saudi Arabia experienced a very high construction boom attracting construction professionals from all over the world. The first national development plan (1970-1975) was established to set up the systematic construction of a modern infrastructure that would lay the foundations for long term strategic goals. In the second plan (1975-1980), there was a sharp increase in government revenues and expenditure for the construction of infrastructure. The budget was increased dramatically in response to available resources and in recognition of the need to rapidly overcome the barrier to economic growth. The government provided the majority of capital investment in the economy while private sector activity was concentrated mainly on construction and trade (Fifth Development Plan, 1990). The construction industry received 69% of total government expenditure during the first national development plan (1970-1975), and 32% during the second (1975-1980) plan (Al-Jarrallah,1983).

The third national development plan (1980-1985) pressed for the completion of infrastructure facilities, maintenance and operation of the existing infrastructure already in place. The second half of the third national development plan was marked by the negative international oil market resulting in an unexpected downturn in the Kingdom's revenues, and consequently, a much lower level of government spending and economic growth.

The fourth development plan (1985-1990) clearly indicated the expected economic changes in the coming five years. During this plan the government has enhanced its future purchasing power by implementing stronger criteria of

control, wider competition and a review of cost levels to adjust to current conditions. In spite of the declining revenues, the government has intended to complete the remaining portion of the infrastructure. The main government's objectives in the field of construction have included the following:

- Strengthening the Saudi construction industry
- Improving the quality of construction and maintenance
- Reducing the cost of construction and related maintenance (Fourth Plan,1985-1990)

The fifth development plan (1990-1995), also, calls for maintenance of the completed infrastructure projects which were subjected to the premature decay resulting from the harsh climatic conditions of Saudi Arabia and low quality standards. Emphasis during this plan has been therefore laid on stimulating the private sector's role in construction maintenance (Fifth Plan,1990). The construction activity of the fifth plan achieved a positive average annual rate of 3.8%. The sixth development plan calls for control of cost of services and increase in the operating life of the facilities, which will lower the future capital budget for these facilities. It calls for development of a complete base information system and producing a periodical report about building and construction. It also advocate support for academic research in the field of construction (Sixth Plan,1995).

1.3 DEFINITION AND IMPORTANCE OF LIFE CYCLE COSTING(LCC)

Due to the popularity of adopting LCC in the construction industry, several agencies started defining what LCC is. The American Society for testing and Material(ASTM) defines the LCC method as:

> A technique of economical evaluation that sums , over a given study period, the costs of initial investment (less resale value), replacements, operations (including energy use), and maintenance and repair for an investment decision (expressed in present or annual value terms). (ASTM, E83-84).

The American Institute of Architects (AIA) defines LCC as:

> A technique that allows the assessment of a given solution or choice among alternate solutions on the basis of considering all relevant economical consequences over a given time (or "Life Cycle"). (AIA, 1977).

The design professionals define LCC as:

> An economical assessment of competing design alternatives considering all significant cost ownership over the economic life of each alternate, expressed in equivalent dollars (Dell'Isola, 1995).

The primary objective of LCC is to provide the management and building owners with a tool that will aid in making management resource decisions.

The starting point of life cycle costing is that all future as well as present costs that arise from an investment decision are important to an owner. So it considers the balance between both initial and future costs and tries to enforce the principle which states "more of this implies less of that ", a tactic which often leads to design decisions offering better value for money (Bishop,1987). The emphasis on initial costs, coupled with the failure to consider the total effect of related cost elements, was considered, by most researchers, as probably the greatest shortcoming in terms of planning, design and construction of many facilities (Mecedo, 1978). Recently, building owners and designers are becoming more aware of the idea that buildings are durable assets which wear out and become obsolete for a variety of reasons and during usage, they will incur running costs that have to be budgeted in advance. Figure 1.1 illustrates what clients might face if they do not show concern about future costs or if they are not well informed of future cost implications (Flanagan,1989).

The life cycle of any building could be divided into four phases:-

Development phase

Design phase

Construction phase

Operation and maintenance phase

Development Phase :

The development phase is the period extending from determination of a requirement, through selection, of a single concept that fulfills the system requirements. During this phase the need for a building is identified , the site

requirements are defined, and preliminary study and implementation plans are prepared.

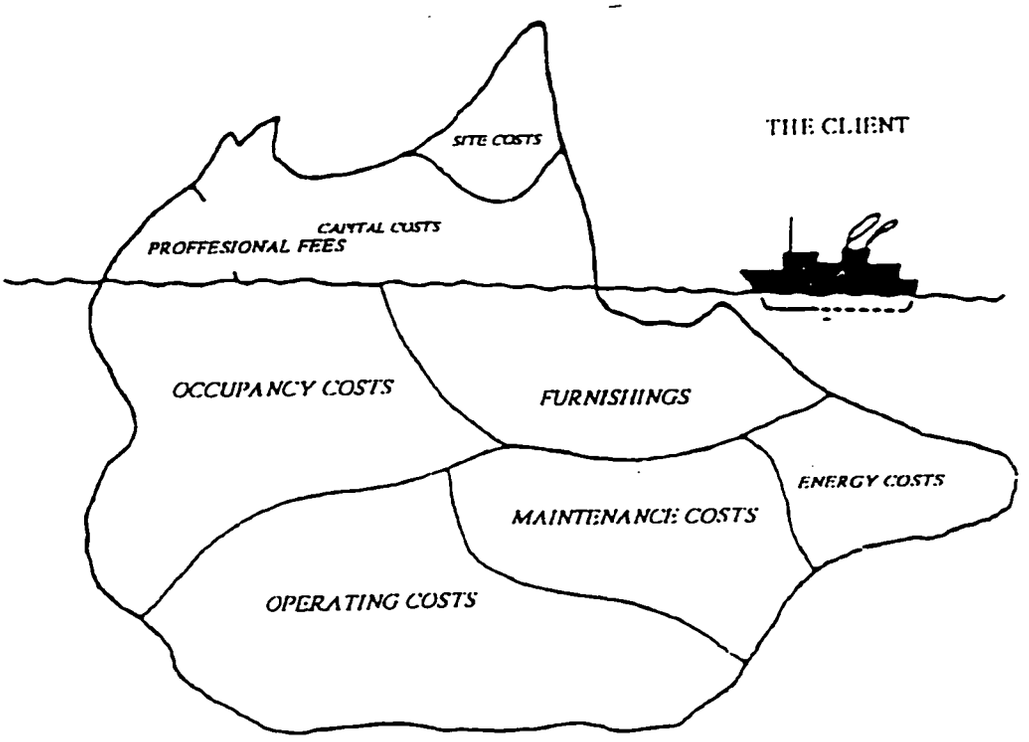


Figure 1-1 The Client and Total Cost Implication (Flanagan , 1983)

Design Phase:

In this phase the requirements of the user are translated into a set of plans and specifications. This phase is comprised of the following sub-phases:

***Conceptual Design Phase*:** It is the period from the establishment of a single concept until all the prime subsystem levels have been identified and their gross performance and design requirements have been assigned.

Preliminary Design Phase: It is the period extending from the establishment of prime subsystem levels through the identifications of all end items

(products) and critical components and the assignment of their performance and design requirements.

Detail Final Design Phase: It is the period extending from the establishment of all performance and design requirements through completion of all detail design requirements and specifications.

Construction Phase

During this phase, the generated plans and specifications are converted into the finished product. This phase extends from the completion of detailed design drawings and specifications through procurement, fabrication, shipment, and installation.

Operation and Maintenance Phase

This is usually the largest phase of the building's life cycle. It starts at initial occupancy and ends when the building is out of the users' hands. Figure 1.2 illustrates the total cost concept and the total cost distribution in building construction. The most economic facility is the one that is designed for the lowest life cycle cost. To concentrate openly on initial cost will give an imperfect view of actual cost incurred. In fact, in some cases, these long term costs can far outweigh the initial cost. Edwin Feldman pointed out that for most buildings, maintenance cost will equal the original cost of construction, as little as two or three decades, as shown on Figure 1.3 (Flanagan ,1983). The importance of considering the total costs, rather than initial costs, can also be seen from Figure 1.4. The figure indicates that for a life of 40 years, the cumulative recurring cost greatly exceeds the initial costs of development, de-

sign and construction. Yet, it is during the early stage of the project that the total cost is determined. Figure 1.5 gives an illustration of those decisions which have the greatest impact on total ownership costs. It can be seen that the main decision makers are the owners, through requirements, as well as the designer. A further point is emphasized in Figure 1.6, where it can be seen that the earlier the LCC is implemented, the greater potential it has to implement changes and thus lower the cost.

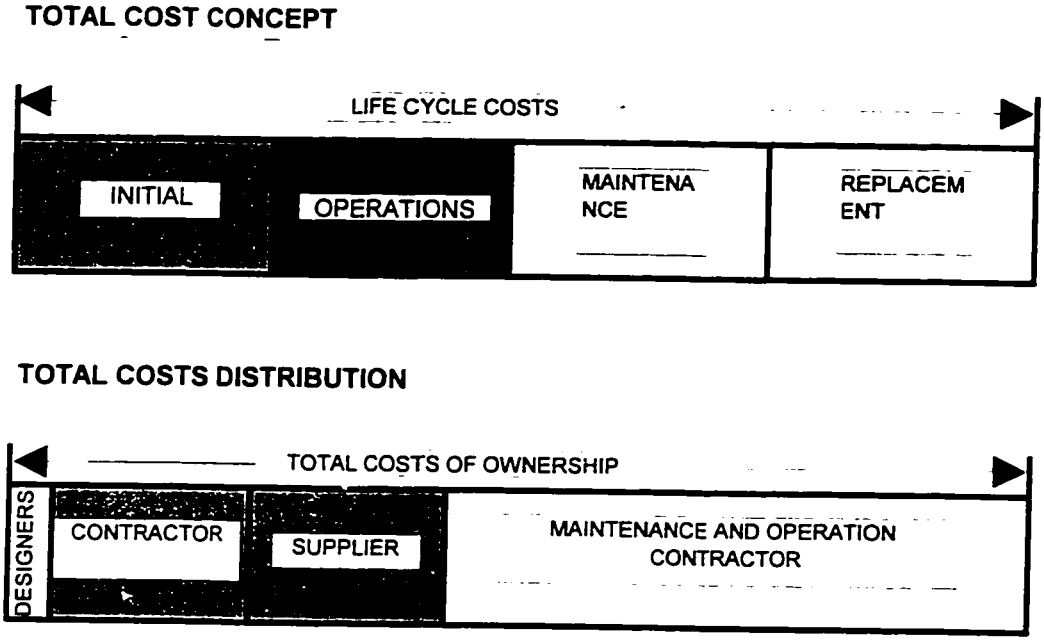


Figure 1-2 : Total Cost Concept and Total Cost Distribution in Building Construction (Macedo ,1978)

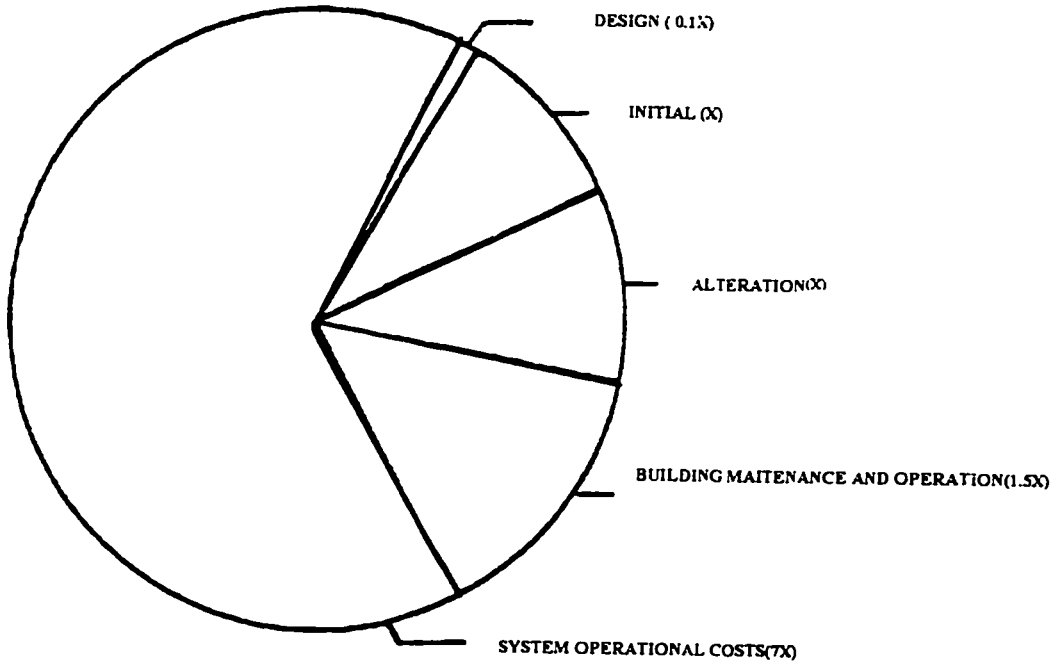
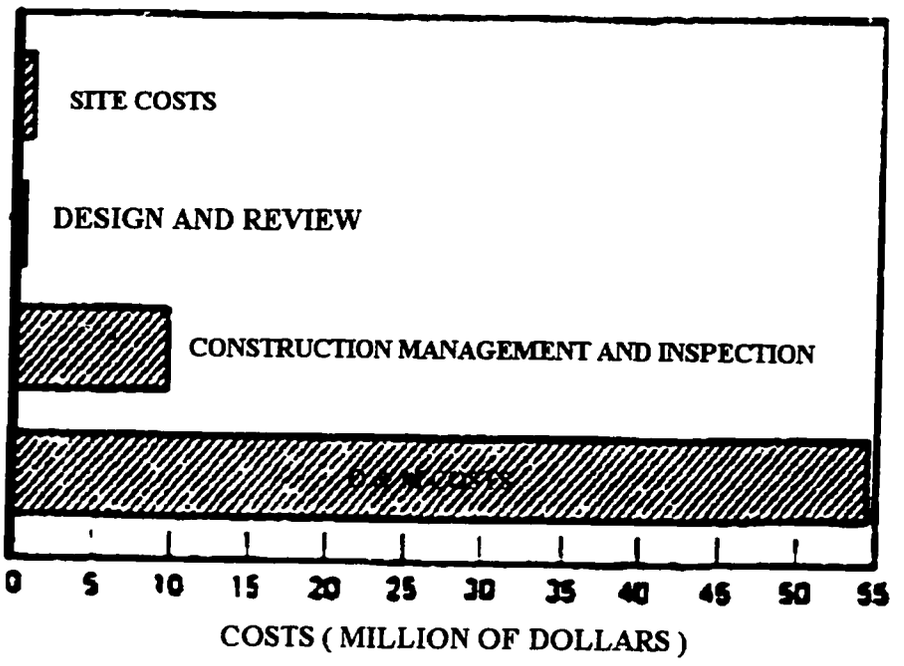


Figure 1-3 : Total Life Cycle Cost (Flanagan, 1983)



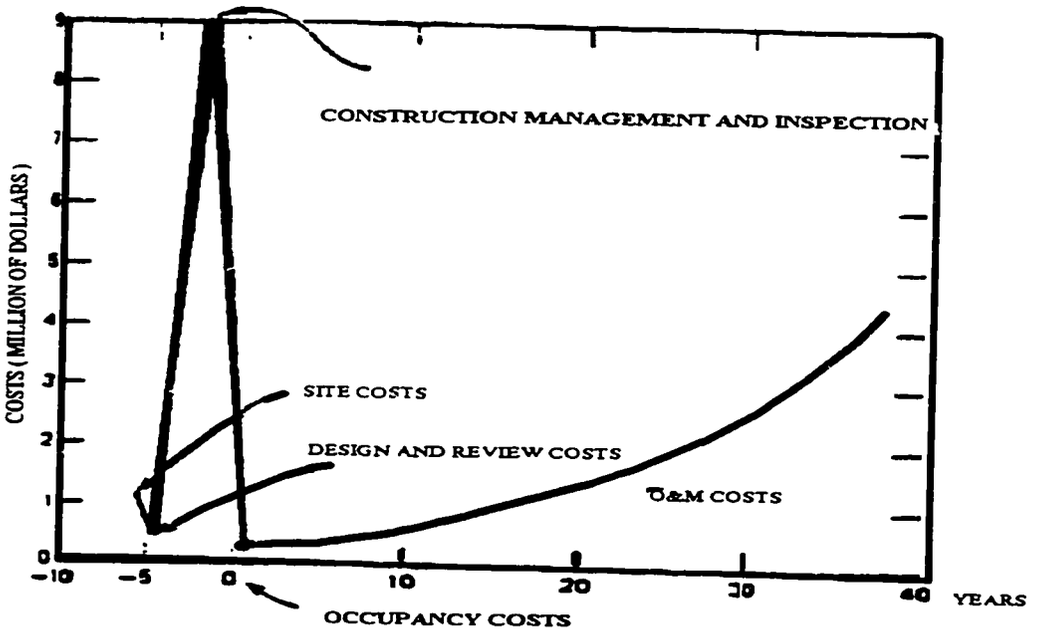


Figure 1-4: Life Cycle Cost for Typical Office Building (Macedo , 1978)

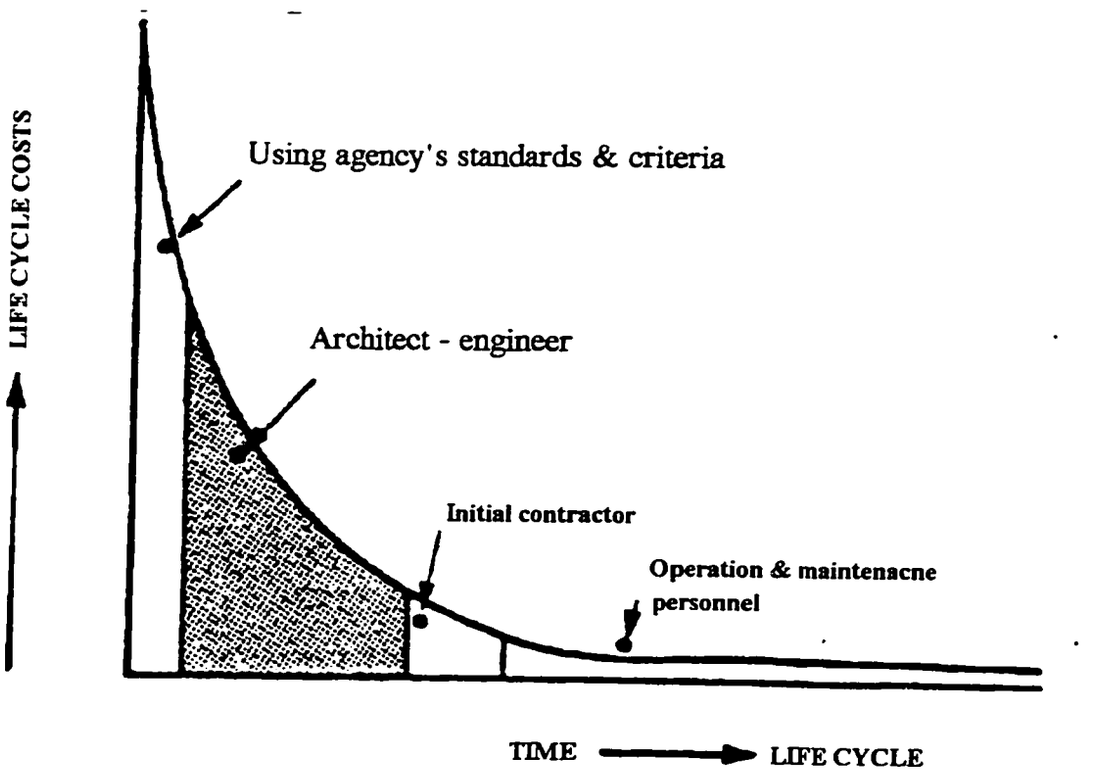


Figure 1-5: Decision - Maker's Impact on Total Facility Costs (Dell'Isola ,1995)

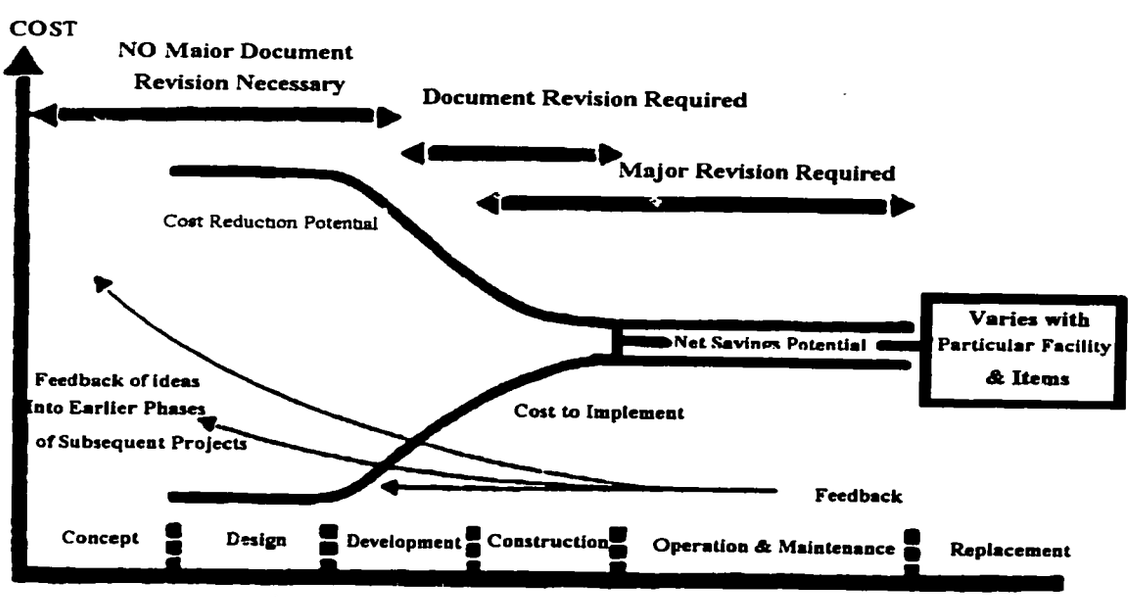


Figure 1-6 : Relationship Between LCC Savings and Implementation Time (Dell'Isola,1995)

1.4 HISTORICAL BACKGROUND

Life cycle costing as an economical technique has existed in one form or another for a number of years. One classical reference to LCC theory and the engineering economy is the book, *Principles of Engineering Economy*, by Eugene L. Grail. The use of LCC has had a long tradition in the U. S depart - ment of defense and was heavily applied in the procurement of weapons and weapon support systems, specially during the world war-II defense build-up. In the health care field, considerable interest is now being shown in the use of LCC. A general accounting office study in1972 revealed that the costs of op- erating and maintaining hospital facilities can exceed the initial project cost in one to three years following construction and the report concluded that " GAO believes that the life cost analysis is essential in the planning and design of all hospital construction projects (Study of Health Care Facilities Construction Costs, report, Comptroller General of the U. S, November 1972). The building industry has been slow in adopting the life cycle cost technique, however. In 1972, Alphonse J. Dell'Isola promoted value engineering (V.E) theories which included LCC, in the construction industry. Dell'Isola was the earliest proponent of V.E. in the construction industry. He published a design guide that reveals the relationships between the design theories and long-term building costs. In 1977, the American Institute of Architects (AIA) published a set of guidelines intended to present the basis of LCC technique as well as an indi cation of where they best fit into the process of planning and design. These guidelines provide designers with the methods of computing LCC and the use of the UNFORMAT cost of account to organize cost data (Life Cycle Cost Analysis: A Guide for Architects). In 1978, the National Energy Conservation policy Act was published : a law that mandates all new federal

policy Act was published : a law that mandates all new federal buildings were to be life cycle cost effective (Dell'Isola,1995). In 1980, the Department of Energy issued the final rule to establish methodology to conduct LCC analysis. In 1983, the American Society for testing and material (ASTM) issued standard practices for computing the LCC of building systems (ASTM E.917-89). Since 1974, many states in the U. S have begun using LCC as a requirement for either administrative directive or legislation in planning, design, and construction of state buildings (Dell'Isola,1995).

1.5 LIFE CYCLE COSTING IN SAUDI ARABIA

It is believed that the introduction of value engineering in Saudi Arabia helped in introducing Life Cycle Costing as an important step towards a complete value engineering (V. E.) study. Value engineering started in Saudi Arabia in the mid-seventies when the General Directorate of Military Works (GDMW) in the Ministry of Defense and Aviation (MODA) sent some of its employees to attend value engineering workshops in the United States in cooperation with the U.S. Corps of Engineers. In 1981, the GDMW sponsored an official introductory conference in Riyadh, where V. E. principles were introduced to more than 150 professionals from various sectors of private industry as well as from government agencies. Since that time the GDMW has shown good progress in introducing V.E. to the public.

Due to some difficulties in the application of LCC as part of V.E. in the GDMW , such as the interrelation of tasks, complexity of various tasks, and large volume of data needed , Issam Kabbani from the GDMW has developed

a computer data-base problem solving system entitled Decision Support Life Cycle Analysis system (DSLCAS) and used it as a prototype tool that will be used in LCC analysis to overcome the above mentioned difficulties. The system increases the effectiveness of decision and the efficiency of the process. The DCLCAS components are shown in fig. 1.7. The system will identify the high cost areas, evaluate design alternatives, perform risk analysis to achieve the least LCC and convey to the user information in the simplest format either tabular or graphical (Kabbani , 1995).

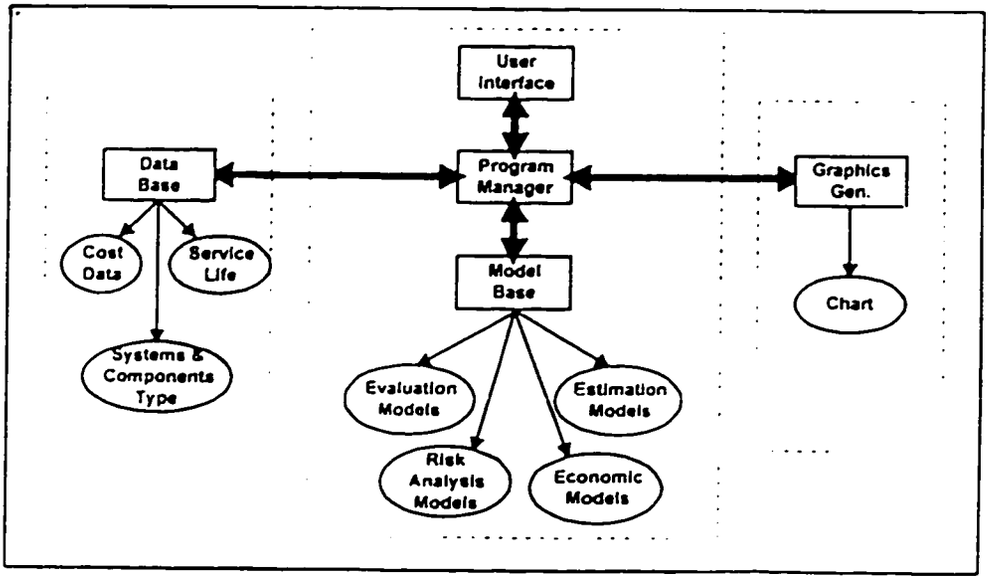


Figure 1-7 : DSLCAS components (Kabbani,1995)

In 1985 (1415 H.) , an administration of planning and budgeting was created in the Ministry of Municipal and Rural Affairs which was aimed at applying and transferring V.E. including the LCC concept to all ministry projects. Savings on some completed projects are shown in fig.1.8

Through these two agencies, LCC is being used formally as part of V. E study. It is not known if Life Cycle Costing has been fully adopted in any other organizations either through value engineering studies or as a separate subject by itself (Value News Report, 1995).

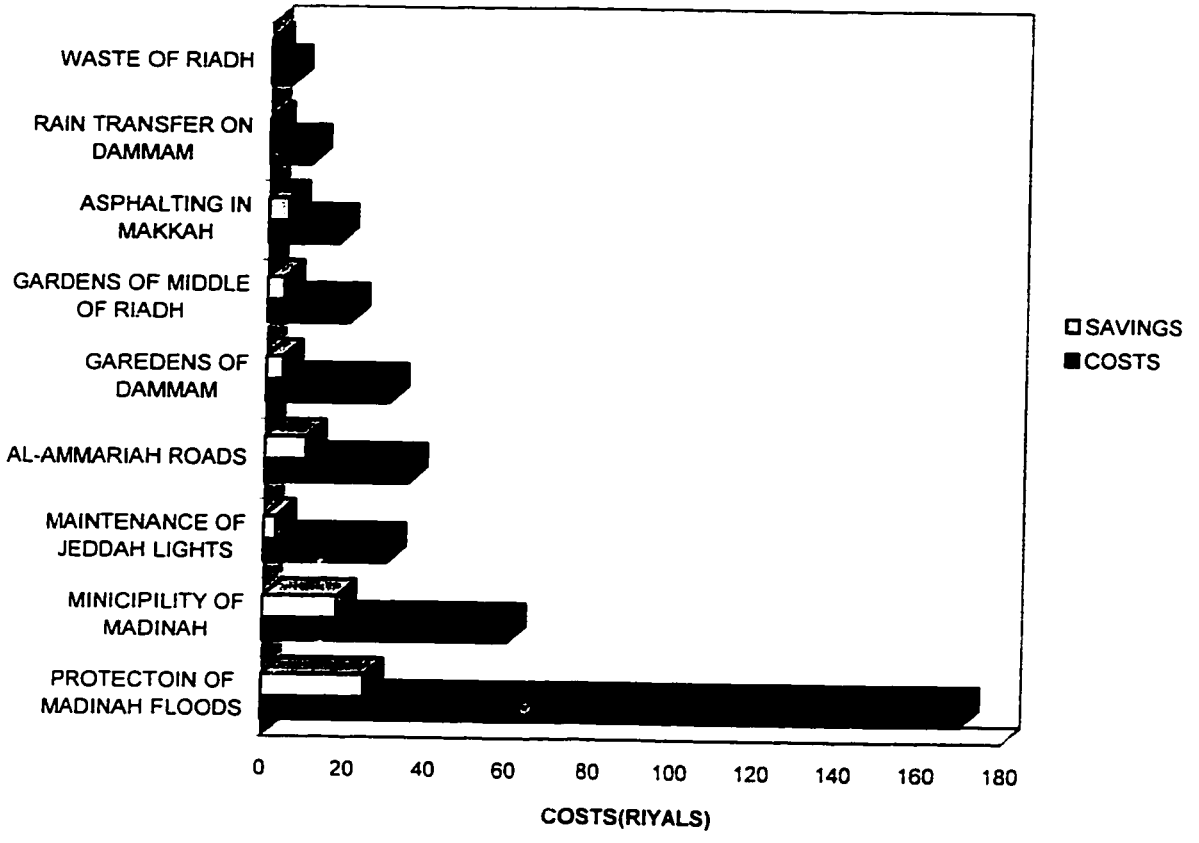


Figure 1-8:Savings on some projects evaluated on 1995 by MMRA (Value Engineering Report ,1995).

1.6 SIGNIFICANCE OF THIS STUDY

In the past, due to the increase of oil revenue, the government objective was the development of infrastructure in a very short time and future costs

that include maintenance and operating costs were not considered . However, recently, it has been discovered that big maintenance budgets have to be assigned to those projects previously constructed without anticipating the future costs of maintenance and operation (Al-Hudhaif , 1995). Moreover, government has started searching for measures that lower expenses on public services which have started to increase dramatically and include ; power, desalinated water, irrigation water, sewage treatment plants, and other forms of operating costs. These expenses can be reduced by searching for alternatives that could lower total costs.

Furthermore, for the additional construction projects, public policy makers have an interest in accomplishing construction tasks at the lowest cost with good quality. The current situation emphasizes the need for the introduction of Life Cycle Costing techniques to optimize ownership costs throughout the life of a project, and not only the initial costs.

1.7 PREVIOUS STUDIES

Although the idea of Life Cycle Costing is an old one, the building industry has been slow in adopting this technique. Aaron Rose, in his paper "Life Cycle Costing Today" mentioned that he conducted a data base search of the status of LCC. The listings shown on Table 1.1 indicate the areas where LCC is used and the extent of activity. Classifications of the references were made on the basis of the information in the complete citation. An analysis of his study reveals that considerable work has been done in a variety of areas on LCC. However, the majority of the LCC studies dealt with only part of the life cycle costing, such as part of the cost, or part of the system, rather than a

complete LCC analysis. He concluded his research by recommending the introduction of the LCC concept (Rose,1984).

Table 1-1 The variety of areas where LCC was considered

Subject	Number of Citations
Air Conditioning	1
Building Design	21
Earth Sheltrer	3
Energy Conservation	24
Heating / Cooling	5
Consumer Products	2
Electronics	6
Geothermal	5
Aquifer Thermal Storage	1
HUD housing	2
Health Facilities	9
Law Enforcement	1
Material Technology	5
Methodology (not otherwise listed)	1
Military Construction	3
Military Systems	38
Space	1
Mobile / Manufactured homes	2
Standard changes	2
Non Conventional Fuels	1
Paving Materials	9
Power Generation	1
Fuel Cell	2
Heat Pumps	2
Hybrid Nuclear	1
Ocean Thermal	1
Overall	2
Photo Voltaic	8
Solar	3
Roofing	3
Solid Wastes	2
Training	1
Transportation	12
Waste Water	1

Another interesting study done by Klaus L. Wuebbenhorst examines how far the construction industry in West Germany understands and makes use of the LCC technique. A questionnaire was developed and sent to 53 producers in the summer of 1982 and was collected in autumn of 1982. The survey showed, that until then, the concept of LCC was relatively unknown and still in its infancy and a need for a further dissemination of the concept seemed to exit. He concluded his study by suggesting that it should be the task of the proponents of LCC to enforce the development in two directions: first, the idea of the LCC concept has to be pointed out continuously. It must be emphasized that LCC has to play an active part in the decision to plan and realize a system. Second, the technique of LCC has to be improved so that it can be adapted to the construction industry (Wuebbenhorst, 1984).

A thesis by Magdy Mahmoud Ahmed Abdul Rahman entitled Floor Finishing Materials and Systems is concerned with designing and developing a computerized expert model for the evaluation and selection of floor finishing materials and systems as a model for developing a comprehensive system for the evaluation of building finishing materials in general. Mahmoud has noticed through his previous research that building material evaluation and selection in the Damman and Al-Khobar areas of the Eastern Province of Saudi Arabia did not depend on rational methodology. He designed a rational evaluation and selecting model incorporating field results which provide the needed data for 58 floor finishing materials and systems. The model was formalized into a computerized expert system to evaluate and select material options based on qualitative and quantitative analysis. The qualitative analysis

sis was concerned with evaluating materials options based on their performance characteristics versus the weighted performance requirement criteria for the specific building's functional space. The quantitative measures were concerned with material options life cycle costing including initial and maintenance cost (Mahmoud, 1993).

1.8 RESEARCH OBJECTIVES

The objectives of this research are to :

1. Find the extent of use of life cycle costing on public construction projects.

2. Explore and evaluate problems facing the application of life cycle costing in the construction industry.

1.9 METHODOLOGY

The research of this thesis will include both a literature review and a field survey. In the first part of the thesis, a broad description of the life cycle costing process, including its fundamentals, methods, and techniques, will be presented. Moreover a broad description of difficulties in application of the concept will be discussed. The second part of the thesis involves a field survey to find the extent of use of LCC. A questionnaire is prepared for both government agencies and consulting offices to investigate the knowledge of the concept, level of adopting LCC, and the economic analysis being used. The remaining part investigates the extent of formal LCC which includes the extent of use, forms of utilizing LCC, source of LCC data, size of LCC staff,

opinion on expansion of LCC and the type of projects where LCC should be enforced. Finally, the severity of a list of twenty six (26) problems was measured and ranked accordingly.

1.10 THESIS ORGANIZATION

This thesis is divided into five chapters. The first chapter gives an introduction to the concept of Life Cycle Costing which includes the historical development of LCC, the construction industry in the kingdom of Saudi Arabia, definition and importance. It also explains the significance of the study, previous studies, the thesis objectives, and the methodology followed. In the second chapter, a detailed description of Life Cycle Costing is given. This chapter presents life cycle costs components, the fundamentals of LCC, and the methodology of conducting LCC. In addition, a detailed description of problems in application of LCC is presented. Chapter three explains the survey methodology, including design of questionnaire, criteria for selecting the respondents, and data collection scheme.

Chapter four is devoted to the statistical analysis of the results obtained from the questionnaires. It includes statistical tables that include frequencies, percentages, and interpretation of those tables.

Chapter five is devoted to a final summary of this thesis and the conclusion reached by the research. Recommendation will be given concerning the extent of use of LCC in Saudi Arabia and suggestions for solutions that could overcome difficulties in the application of the concept will be provided. Fi-

nally, additional areas for further research in this field are indicated. A thesis organization chart is shown on figure 1.9.

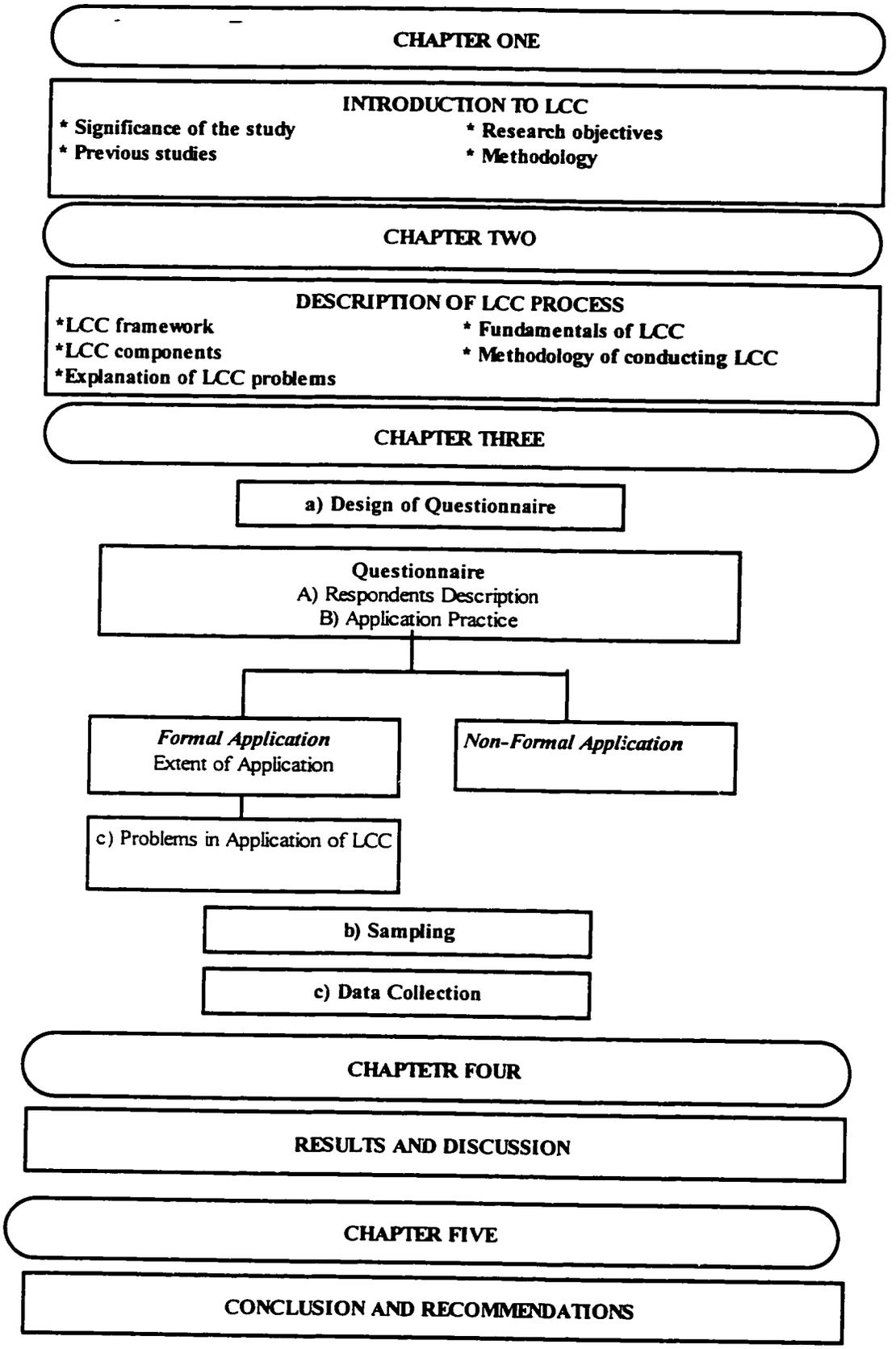


Figure 1.9 Thesis Organization Chart

CHAPTER 2

THE LIFE CYCLE COST PROCESS

2.1 LIFE CYCLE COST ESTIMATING FRAMEWORK

The standard estimating framework is the 16-division Construction Specification Institute (CSI). This framework could be used as a data communication medium in the building industry, similar to specifications, product data, and project management systems. It could also be used as a cost control and estimating framework. However, it is inadequate during the project budgeting and early design stages because it is material and product oriented and cannot be used for decision making in selecting material alternatives. Because of this the US General Services Administrative (GSA) has issued a draft outline of the uniform building component format (UNIFORMAT) which defines building systems based on an elemental format that involves the separation of a building into its component functional parts, elements, or subsystems. At the same time, the American Institute of Architects began the development of a master format. The two formats were merged because they were similar. The various levels of detail of UNIFORMAT and their relationship with CSI divisions are presented in figure 2.1 (Dell'Isola, 1995).

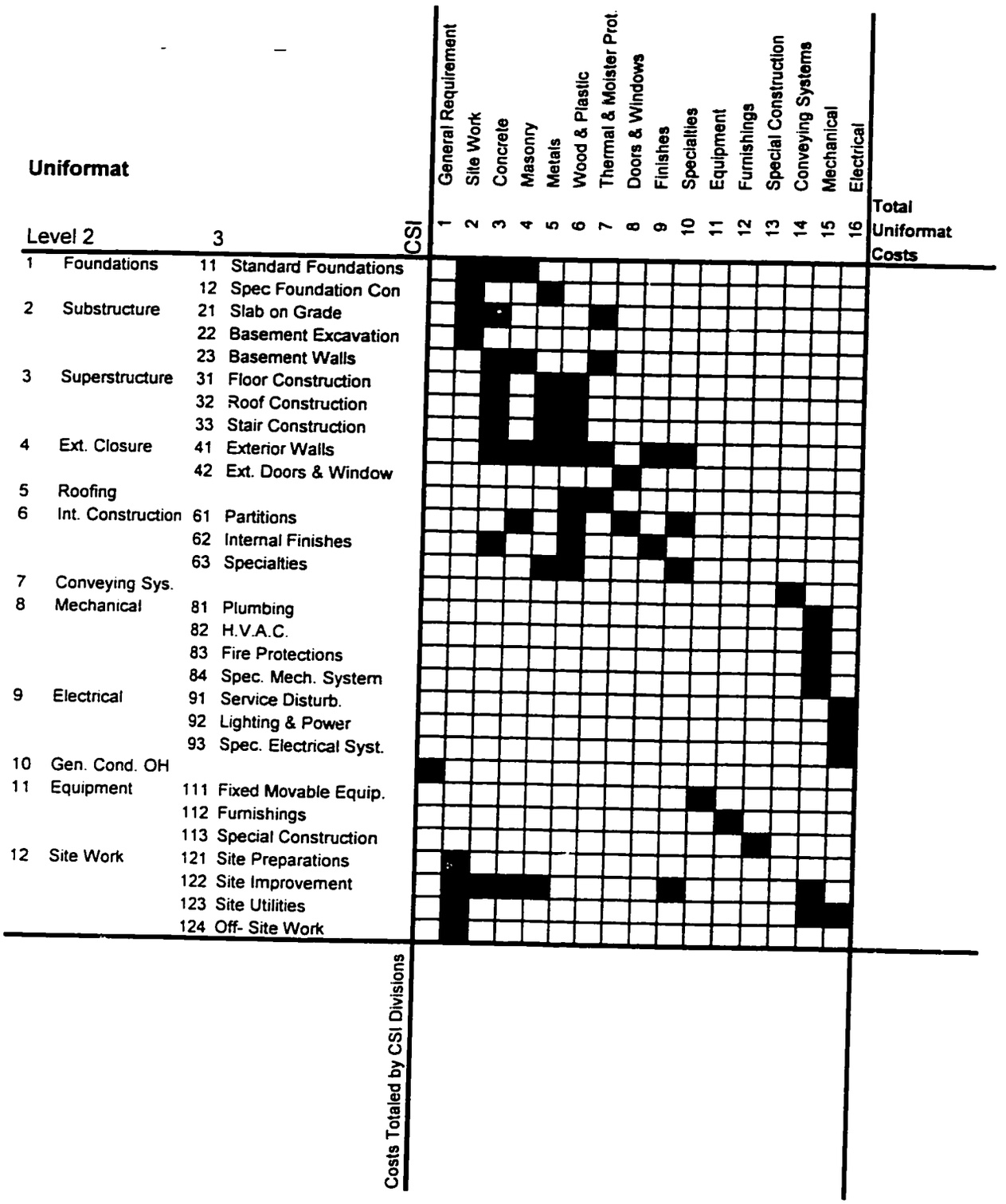


Figure 2-1: Relationship Between UNIFORMAT and the CSI (Dell'Isola, 1995).

LCC Components

The American Institute of Architects (AIA) has established the following cost categories (LCC components) (AIA, 1977)

- Initial Capital Investment Costs.
- Financing Costs.
- Operation and Maintenance Costs.
- Replacement Costs
- Alternation and Improvement Costs
- Associated Costs.
- Salvage Costs.

Table 2.1 explores in detail the above suggested categories .

Table 2-1 : Cost Factors for Possible Use in Life Cycle Cost Analysis (AIA, 1977)

Cost Category	Description	Cost Category	Description
INITIAL CAPITAL INVESTMENT COSTS Costs associated with the initial planning design and construction of the facility	Land cost, including costs of acquisition options, survey appraisals, demolition and relocation, legal and filing fees. Design costs, including cost of consultants, and/or in-house staff as well as required special studies or tests (e.g. test boring). Construction costs, including cost of labor, materials equipment, general conditions (job overhead), contractor's main office overhead and profit. Other owner costs, including cost of owner project administration, construction, insurance, permits fees and other expenses not included.	FACILITY REPAIR AND REPLACEMENT COSTS. Costs associated with restoring the facilities to its original performance.	Costs of major repairs to building elements during the analysis time. Costs of planned replacements of building elements during the analysis time include costs of planning, design demolition and disposal and other owner costs, as well as costs for labor, materials, equipment, overhead, and profit of any outside contractors.
		FACILITY ALTERATION AND IMPROVEMENT COSTS. Costs associated with planned additions, alteration, major reconfiguration and other improvement to the facility.	Costs of all planned capital improvements during the analysis time include costs of land, planning, design, demolition, relocation, disposal and other owner cost as well as cost of labor materials, equipment, overhead and profit of any outside contractors.

Table 2.1 : (Contd.) Cost Factors for Possible Use in Life Cycle Cost Analysis

Cost Category	Description	Cost Category	Description
FINANCING COSTS Costs associated with financing capital investment.	Loan fees and one-time finance charges associated with borrowing for the project, both for initial project development as well as major capital increments. Interest costs for short term (interim) financing Note: Interest costs for long term (permanent) financing usually are considered in establishing the discount rate for the life cycle cost analysis and are not included as costs in the analysis proper.	FUNCTIONAL USE COSTS. Costs associated with performing intended functions within the facility.	Salaries and benefits of personnel working in the facility, as well as supplies and services required for the program housed in the facility. Income and real program taxes, Denial-of-use and lost revenue costs associated with delayed or inappropriate scheduling of occupancy, or with using the facility inefficiently. Includes continuing rent, unexplored leases, operating in obsolete facilities, etc.
FACILITY OPERATION AND MAINTENANCE (O &M). Costs associated with the ongoing operation and maintenance of the facility.	Personnel costs for routine maintenance, cleaning grounds care, trash removal, space reconfiguration, security building operation, property management, etc. Costs of fuel, utilities, supplies equipment and contract services associated with these activities should also be included.	SALVAGE COSTS. Costs (or values) of building elements or facilities salvaged during the life cycle.	Costs of salvage operation, including demolition and disposal if not included above. Salvage values of building elements or facilities recovered as part of replacement alteration or improvement activities.

2.2 ESTIMATION OF LCC COMPONENTS

During life cycle cost analysis, costs could be ranged from actual billed amounts to gross estimates. There are three LCC estimating techniques (Gage, 1994):

- Parameteric Analysis : Typically uses a mathematical model and estimates cost based on one or more system characteristics such as weight or size.

- Analogy : Uses cost data from an existing system that is similar in design and /or operational environment, and adjusts the costs to account for differences between the two systems.

- Bottom-Up or Engineering: Cost estimates are developed for each element of system cost, based on functional expertise, and consolidated at the system-level to develop the cost of the entire system.

Some sort of estimating frame has to be available and it should include provisions for organizing the various types of costs that include: initial costs , operating costs , ...etc.

2.2.1 Estimating Initial Costs

Initial cost or project related cost is the owner's associated costs and it includes design consulting, legal costs, and other professional fees. The non-related and constant costs, such as land costs, are not considered since they provide the same impact in any given design solution. However, if the

purpose of the facility study is to find the actual life cycle costs then such costs should be included in the analysis. Figure A-1 in Appendix A illustrates the relative cost impact and the percentage of such cost for a typical office building. Decisions based exclusively on initial costs are easy to handle for most designers. However, when performing LCC analysis, the decisions concerning the relationship of the initial cost to total ownership cost are more complex and more interrelated with other disciplines (Dell'Isola, 1995).

2.2.2 Estimating Operating Costs

Energy costs cover a sizable portion of operating costs. Therefore, energy costs are a significant total cost driver in facility LCCA (Quems, 1994). The energy costs fall into categories of heating, cooling, ventilation, domestic hot air, lighting and other items. The impact of energy cost for a typical office building is shown graphically in Figure A-2, Appendix A, according to the UNIFORMAT system categories. The figure shows that lighting has the most significant influence on energy, contributing as much as 48 percent from direct lighting with an indirect influence of additional heat in the space (Dell'Isola, 1995). A more skillful operation of buildings satisfying the standards could help in compensation for energy needs. The energy consumption cost is found by multiplying the consumption rate by the hours of operation. In practice , it is difficult to design operating strategies that will lead to the lowest life cycle cost. However, the behavior of material and mechanical systems could be adjusted along with likely uses of the building and the environmental conditions to which they are exposed (Coullahan,1996).

The operating cost is relatively easy to estimate using derived energy models from specific publications, such as the ASHREA SYSTEM Handbook for determining of HAVC consumption.

2.2.3 Estimating Maintenance and Repair Costs

The prime benefits of maintaining a building are to retain the value of investment, to fulfill its function, and to present a good appearance to the public. It is important to ensure that the available maintenance sources are applied properly and reasonably to most requirements. Maintenance cost is the most significant cost, although it has received the least attention in many researches. In order to improve the maintenance of buildings, owners and designers, in their selection of materials during design, should consider the implications on the future maintenance of the facility such as :

- The choice of exterior and interior finishes.
- The selection of lighting fixtures, floor covering materials, and other interior elements that have minimum routine repair and replacement costs.
- The decision whether or not to a plan a preventive maintenance program that will have implications for the selection of facility's equipment.

Figure A-3, Appendix A, shows the relative percentage of annual maintenance costs for a typical office building. As shown in the figure, HVAC sys-

tem, plumbing, and the interior construction have the most significant effect on maintenance costs.

Sources for obtaining historical information are rather limited. BOMA Experience Exchange Report provides summary information on the average dollars per square foot for maintaining office buildings (BOMA , 1990). Another published source is the book Life Cycle Cost Data where the author of this book has gathered information in a form suitable for use by the designers dealing with maintenance, operated demand and replacement (Dell'Isola , 1983).

2.2.4 Estimating Replacement Costs

Building replacement costs include the cost of replacing the equipment or other facility elements that have an estimated life shorter than the life of the building. Typical decisions based on replacement costs include :

1. Whether to specify short life building elements, such as roof top HVAC units or shorter life roofing materials.

2. Whether to specify short life elements in areas that may undergo significant future alterations.

Figure A-4 in Appendix A provides an approximate percentage for annual costs for each UNIFORMAT category.

2.2.5 Estimating Alteration Costs

Alteration Costs: They are the expenditures used for anticipated modernization or changes required to accommodate building functions not originally intended. The relative costs of alterations for the various UNI-FORMAT categories are approximately 72% for interior construction, 12% for the HVAC and 16% for electrical (Dell'Isola, 1995). The consideration of whether the decision to minimize alterations will lead to inefficiency in space flexibility for the future, even for facilities that do not anticipate high cost alteration programs, should be included. The decision of construction that will effect alteration cost, such as whether to plan for movable partitions, utilities in the exterior walls, knockout panels, and other design options that facilitate alterations should be considered.

2.2.6 Estimating Associated Costs

Associated costs have been neglected by many LCC studies, although they play a significant role in the analysis. These include administration costs, functional costs, and other costs.

Administrative Costs include the costs associated with managing building maintenance and repair requirements.

Functional Use Costs include costs of material, and other items required to perform the functions of the organization using the facility. Functional use costs are the highest in hospitals. They correspond to 35% and are the least considered during planning in many projects. The magnitude of functional use costs will vary greatly depending upon activities in different buildings

(Ward,1987). Some decisions that have implications on the functional use costs are as follows:

- Whether to select a design with higher constant costs but lower functional-use costs
- Whether to offer the services through contract concession or facility staff.

Other Costs are costs that may include any identifiable expenses related to a facility not covered in the other categories, such as security, real estate taxes, and fire insurance (Dell'Isola,1995) .

2.2.7 Estimating Salvage Cost

This category includes the costs of salvage function as well as demolition and disposal. The salvage value (retention value) is estimated based on the remaining percentage of the component's remaining useful life, multiplied by the component's initial cost. The salvage value can be calculated as follows:-

$$\textit{Percentage of remaining useful life} = \frac{\text{useful life} - \text{up to study period}}{\text{useful life}}$$

(2.1) (Kabbani , 1996)

Salvage value = percentage of remaining life $\times$ initial cost. (Kabbani, 1996).

2.3 LIFE CYCLE COSTING FUNDAMENTALS

The investor normally considers all future and present costs important to investment decisions.

CASH FLOW DIAGRAMS

The cash flow diagram is used as an aid in the visualization of cash flow, expenditure (or outlays) and income (or receipts). Figure 2.2 illustrates this concept.

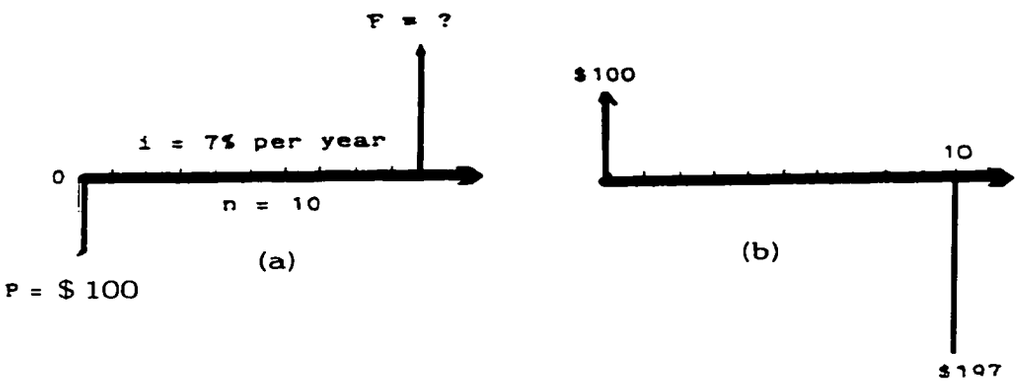


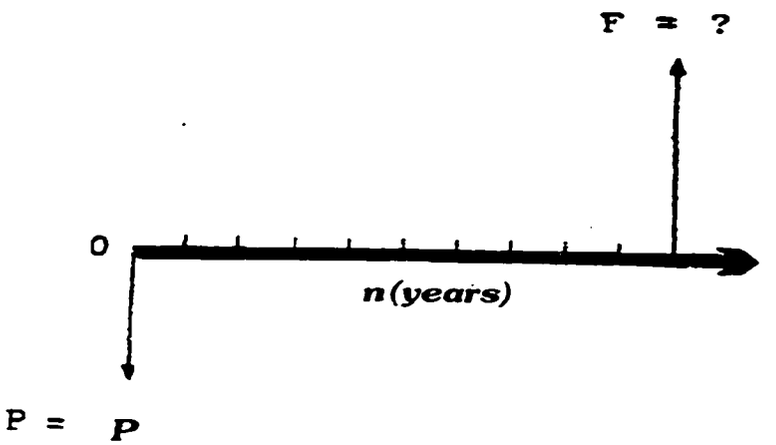
Figure 2-2 Representation of Cash Flow Diagram

The horizontal line in figure 2.2 represents the time axis with a scale normally graded by years. The cost is represented by an arrow whose length is proportional to cost magnitude. Whether a cash flow is shown as an income or an expenditure depends on the point of view of the presenter of the diagram. For instance, to an investor who places $ 100 in a bank and allows it to re - main there, earning 7 percent interest for 10 years, the cash flow diagram

would look as in Figure 2.2a. On the other hand to the bank, the cash flow would look like the Figure 2.2b.

2.3.1 Determining Compound Future Value

In this case the concern is to know what value will exist at end of the specified year. This means that for a single deposit or payment of P, earning i percent and after n number of years what will be the value of the future value of investment F. In this case, the investment will be represented by the following cash flow diagram :



Cash Flow Diagram For Compound Future

By using the following terminology;

P = present value or principal at the end of year.

i = annual investment rate (interest rate).

I = amount of investment (interest) earned during the year.

F = Principal at end of n years, or future value.

n = number of years

The interest (I) = (Principal)(Number of Periods) (Interest rate)

$$I = P \times n \times I \qquad (2.2)$$

The compound interest may be considered as the interest on top of interest. This means : the amount of money accumulated after the first year will be equal to:

$$F_I = P + P_I = P\,(1+i)$$

After the end of the second year, the amount accumulated (F2) will be equal to the amount that had accumulated after year 1 plus interest from the end of year 1 to the end of year 2, thus,

$$F_2 = F_1 + F_1 i = F_1\,(1+i)$$

$$F_2 = P\,(1+i)(1+i) = P\,(1+i)^2$$

In general, this could be expressed by

$$F = P\,(1+i)^n \qquad (2.3)$$

The term in the bracket is called the *Single Compound Amount Factor (SCAF)*. By using the standard notation form : $\left(\frac{X}{Y},i,n\right)$, where : X represents the unknown, Y represents the given , *i* represents the interest rate, n represents the periods.

Example : We would like to determine what value will exist at the end of the third year if a single deposit payment of $10,000 is made at the beginning

of the first year and the deposit balance earns as 6% return of investment.

Solution : In this case $P = \$10{,}000$, i=6 %, **n**= three years

Then : By using Eq. (2.3).

$$F3 = 1000\,(1 + 0.06)^3$$

In addition, previous single compound amount factor (SCAF) could be expressed for the above example as follows:

$$\left(\frac{F}{P}, 6\ \%\ , i\right)$$

As a shortcut solution to such problems, a series of investment factors have been calculated in Appendix C for different rates .Table 2.2 shows the SCA factors which are extracted from the first column of different interest ta - bles for various rates.

Table 2-2 : Single Compound Amount Factor (Column 1 , Appendix C)

Year	6%	10%	15%	20%
1	1.060000	1.100000	1.150000	1.200000
2	1.123600	1.210000	1.322500	1.440000
3	1.191016	1.331000	1.520875	1.728000
4	1.262477	1.464100	1.749006	2.073600
5	1.338226	1.610510	2.011357	2.488320

2.3.2 Determining the Present Value

In the previous section, the concern was to find the present value of bal- ance at a specific time in the future. In this section, we want to determine for the known future receipt what must be paid at present. The present value is a

concept based on an idea that money has time value. That means one dollar received now is better than the same dollar received after one year because the first one could be invested in some opportunities that will earn profit for one year while the other will not.

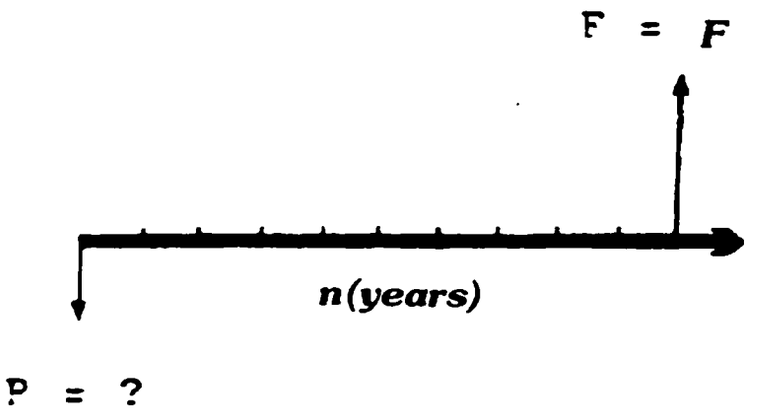
In order to find how much must be paid at present in order to arrive at a specific value in future , an adjustment factor called a *Discounting Factor* will be used. By recalling equation (2.3)

$$F = P(1+n)^n \tag{2.3}$$

By expressing **P** in terms of **F** in the equation, it will result in the follo ing equation:

$$P = F\frac{1}{(1+i)^n} \tag{2.4}$$

The expression in brackets is called the *Single Payment Present Worth Factor(SPPWF)* which allows the determination of present worth **P** of a given future amount **F** after **n** years at interest rate of ***i*** . The cash flow diagram presents this case as fol lows:



Cash Flow Diagram for Single Payment Present Worth

The *SPPWF* is the reciprocal of the *SCAF* . The standard notation used to express the SCAF is $(\frac{P}{F}, i, n)$.

Example : What will be the future value of \$11,906 if it is invested for three years with interest rate of 6% ?

Solution : The present amount will be determined as follows:

$$\because \quad P = F\left(\frac{P}{F}, i, n\right)$$

Then $P = 11{,}906\$ \times 0.839 = \$1{,}000$

The second column of investment tables in Appendix C corresponds to the SPPW factors. Different SPPWF for different rates are presented on table 2.3

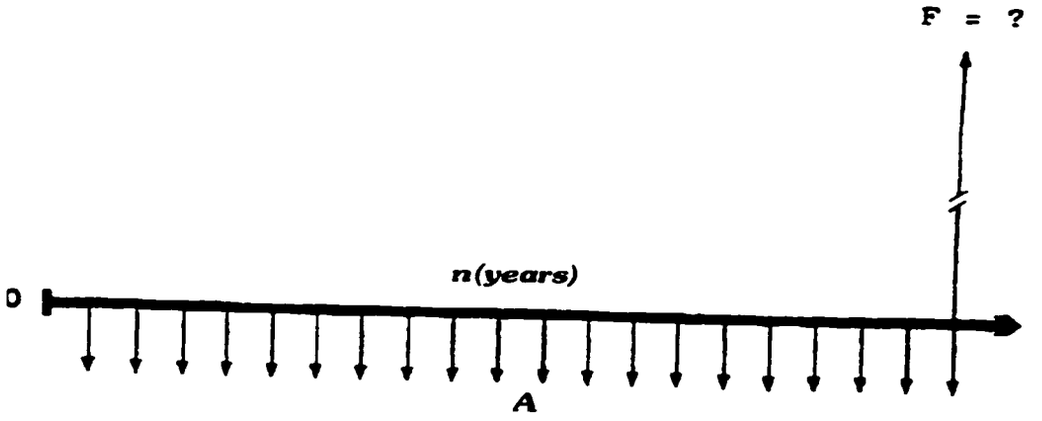
Table 2-3 : Single Payment Present Worth Factor (Column 2 , Appendix C)

Year	5%	6%	10%	15%
1	0.952381	0.943396	0.909091	0.869565
2	0.907029	0.889996	0.826446	0.756144
3	0.853838	0.839619	0.751315	0.657516
4	0.822702	0.792094	0.683013	0.571753
5	0.783526	0.747258	0.620921	0.497177

2.3.3 Compound of Future Value of Annuity

In this section, a series of equal deposits or payments will be made at equal intervals and we want to know the future value at the end of the specified year. In this case if a deposit of **A** is made at the end of each year for n years

at an annual investment of *i*, what would the future value be at the end of the period ? The cash flow diagram will be shown as follows :



Cash flow diagram for uniform compound amount

It will be logical in this case to assume that every deposit (A) made at each interval will present the value of a future amount, and accordingly, to compute the sum of all deposits made in each succeeding year and include earned investment or deposits only when they are earned. The general formula for a single value will be used ;

$$F = P(1+n)^n$$

Thus for multiple series :

$$F = P(1+i)^{n-1} + P(1+i)^{n-2} + \ldots\ldots\ldots + P$$

P will be expressed by an annuity referred to as A. Then

$$F = A(1+i)^{n-1} + A(1+i)^{n-2} + \ldots\ldots\ldots + A \qquad (2.5)$$

multiplying the above equation by (1+i) then

$$F = A(1+i)^n + A(1+i)^{n-1} + \ldots\ldots\ldots + A(1+i) \qquad (2.6)$$

Applying equation(2.6) -equation(2.4) will result in

$$F = A\left(\frac{(1+i)^n - 1}{i}\right) \qquad (2.7)$$

The term in the bracket is called the Uniform Series Compound Amount Factor (USCAF). If this factor is multiplied by the uniform annual amount A, the result will be the future worth of the uniform series which is referred to by the standard notation:

$$\left(\frac{F}{A}, i, n\right)$$

Example: What is the future value of $1000 deposited annually at 5% for five years ?

Solution: $\because F = A \times \left(\frac{F}{A}, i, n\right)$

Then : $F = \$1000 \times 5.525631 = \$5525.63$

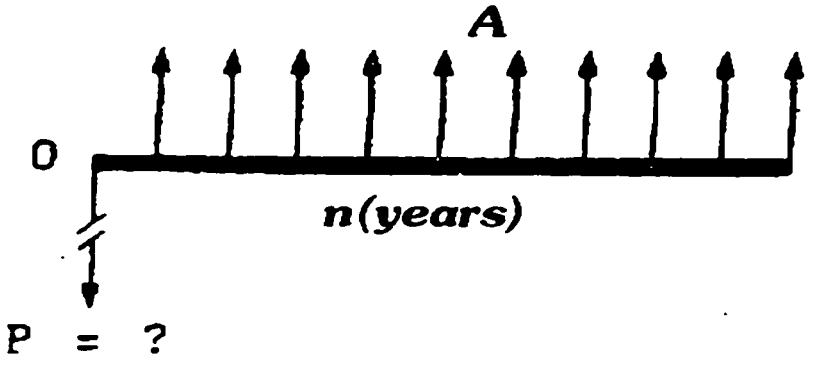
USCAF is presented in the fifth column of investment tables in appendix C. Table 2.4 also shows the USCAF for different rates.

Table 2-4 : Uniform Series Compound Amount Factor (Column 5 , AppendixC)

Year	5%	6%	10%	15%
1	1.000000	1.000000	1.000000	1.000000
2	2.050000	2.060000	2.100000	2.150000
3	3.1525003	3.183600	3.310000	3.472500
4	4.310125	4.374616	4.641000	4. 993375
5	5.525631	5.637093	6.105100	6.742381

2.3.4 Present Value of an Annuity

In this section, the concern is with the present value of a series of annual receipts as the investment produces income over time. The cash flow diagram will be presented as:



Cash flow diagram of present worth of annuity

$$F = P(1+i)^n$$

By expressing **P** in equation in terms of **F** in equation (2.3), it will result in the following equation;

$$P = F\frac{1}{(1+i)^n}$$

To consider the receipt value of an annuity, P, we have to consider the sum of the individual present values of all receipts . This could be done by modifying the basic present value formula and expressing F by A as:

$$P = A\left[\frac{1}{(1+i)} + \frac{1}{(1+i)^2} + \ldots\ldots\ldots + \frac{1}{(1+i)^n}\right]$$

Avoiding lengthy detail, the final simplified form will be the following;

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \qquad (2.8)$$

The term in the bracket is called the Uniform Series-Present Worth Factor (USPWF) which may refereed to by standard notation (P/A, i, n). Then

$$P = A\left(\frac{P}{A}, i, n\right)$$

Equation (2.8) could be arranged as :

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \qquad (2.9)$$

The term in the bracket is called Capital Recovery Factor (CRF) which yields the equivalent uniform annual cost **A** over **n** years of a given investment **P**, when the interest rate is ***i*** (Assaf,1994).

Example : Assuming that for individual is considering an investment that will provide a series of annual cash receipts of $500 for a period of six years, and interest of 6 percent, how much must be paid by the investor today ?

Solution: This can be done by considering the present value of a 500 dollar receipt at year 1. Using the equation (2.9) then

Then $$P = 500\frac{(1+.06)^5 - 1}{.5(1+.06)^5} = \$669$$

USPWF could be found from column 6 of the investment tables. USPWFS for selective rates are shown on table 2.5.

Methods of Performing LCC

Life cycle costing can be accomplished using either the *Present worth method or the Annualized method.* Both methods provide a valid measure of life cycle cost. The present worth method allows the conversion of all present and future costs to a single point usually at or around the time of first expen-

diture. Tabular solutions for the known formula, $P = F\frac{1}{(1+i)^n}$, are available in most engineering economic books for a range of values for n and *i* (*See Appendix C)*. The annualized method is used to convert dollars expended over variant points to an equivalent cost. A majority of researchers prefer to use the annualized method since running costs and energy consumption, that can be best presented by the annualized method, form a large percentage of the total LCC (Bishop,1984).

Regardless of the methods used to measure LCC, several pertinent points must be examined, such as period of analysis and discount rate.

Table 2-5 : Uniform Series Present Worth Factor(Column 6, Appendix C)

Year	5%	6%	10%	15%
1	0.952381	0.943396	0.909091	0.869565
2	1.856410	1.833393	1.735537	1.625709
3	2.723248	2.673012	2.486852	2.283225
4	3.545951	3.465106	3.169865	2.854978
5	4.329477	4.212364	3.790787	3.352155

•Period of Analysis

The period of analysis is the time frame selected for which the analysis of the accumulated costs will occur. Selecting the period of analysis depends on the owner's objectives and his organization's policy. A recommended analysis period is shown in figure 2.3. The most crucial point in LCC is selecting the

starting point of analysis because most costs incurred prior to the base-line period are considered "Sunk Costs", that is, all costs that are previously expended and can't be recovered. The present time marks the beginning of the analysis period or the time to which all life cycle costs are discounted for combining and comparison. It is usually chosen from among the points identified in figure 2.4. Mostly, the common choices for the present time are point B, point E, and point G. Selection of point B normally results in the most realistic base line costs which could be developed from contractors' quotes or other sources of today's cost. (Dell'Isola,1995)

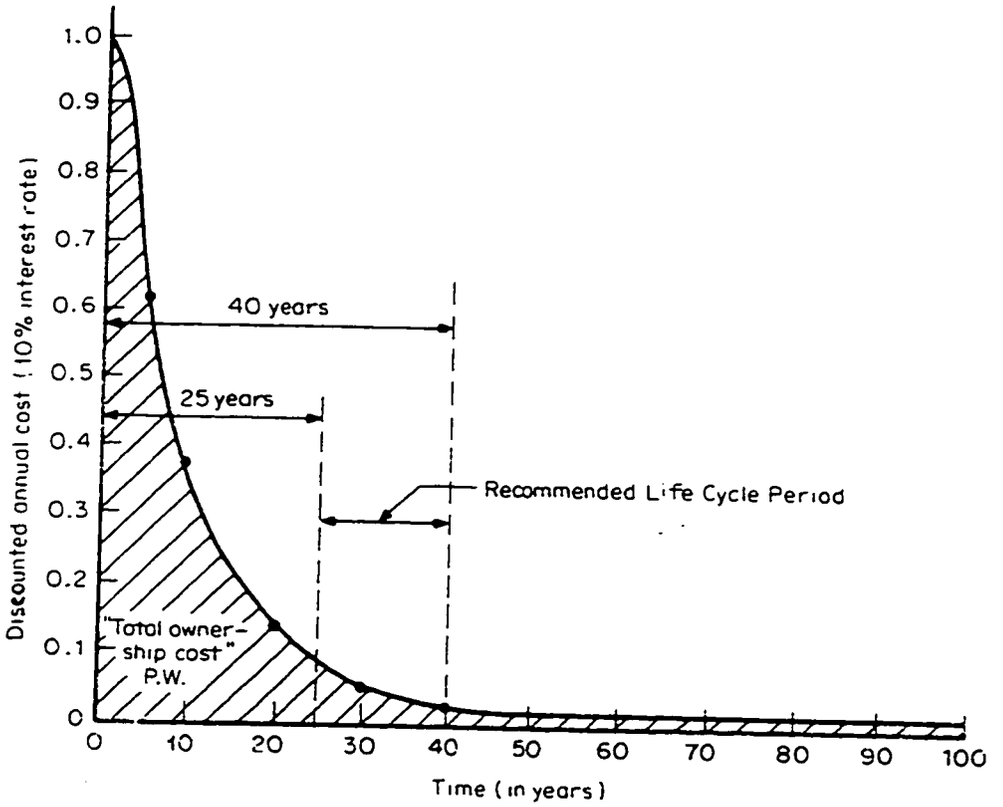


Figure 2-3:Recommended analysis period (Dell'Isola,1995).

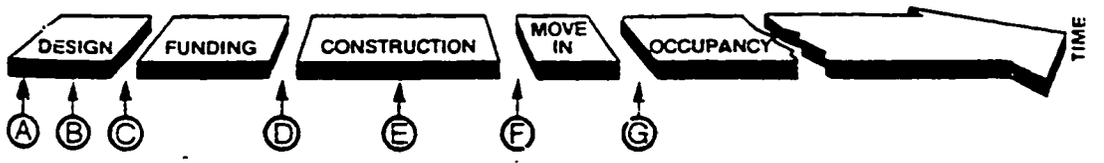


Figure 2-4:Present time diagram (Dell'Isola,1995).

- **Discount Rate**

It is important to distinguish between the interest rate of return and the discount rate. The interest rate merges both the time value of money and the impact rate of inflation whereas the discount rate will be typically obtained from inflation (Brandon,1992) . The normal discount rate ***i***, and the real discount rate **r** are related as follows;

$$r = \left[\frac{(1+d)}{(1+i)} - 1\right] \cdot 100$$

r = net of inflation discount rate

d = discount rate including inflation (the normal or real discount rate)

i = inflation rate

It is important that options are analyzed on the same basis. That means whether or not we should include the effect of inflation. This will be governed by the estimation criteria: if the estimation for cash flow is done including inflation, then the nominal discount rate is used. On the other hand if the estimates are in current prices excluding any allowances for inflation, a real discount rate is used. The constant dollar approach, with a real discount rate, is most commonly used by government or non-profit organizations, where taxes are not applicable. However, current dollar is normally used in industrial projects, where items are expected to rise or inflate above general prices and are referred to by "the differential Escalation". For private investments subject to LCC, the analysis is usually conducted by the current dollar approach using the nominal discount rate (Kabbani, 1996). It is difficult to

choose which criteria is to be followed. However, a good approach is that if prices are expected to inflate at the same rate then a real discount rate should be used, and if prices are to inflate at different rates the calculations should be based on nominal terms with explicit account being taken of the differential rules of inflation. Selection of the rate value is also an important criteria. Normally the right discount rate will depend on the circumstances and objectives of the client, such as whether the client is financing the project through borrowed money or from capital cost (Flanagan,1989). If the project is financed through borrowing, then the actual discount rate is the actual cost of borrowing including inflation if calculations are in real terms. In contrast, if the project is financed through capital, then the discount rate will be determined by the current and future rate of return the market expects from the least alternative used (Brandon,1992). The discount rate is a critical variable in the analysis, in that the decision to proceed with the project will be crucially affected by the discount rate chosen. Too high a discount rate will lead to decisions in favor of short term, low capital cost options, while too low a discount rate will give undue bias to future cost savings. In this case, nominal discount rates are used. Private investment, subject to LCC analysis, is usually conducted by the current dollar approach using the nominal discount rate (Kabbani, 1996).

2.4 LIFE CYCLE COSTING METHODOLOGY

INTRODUCTION :

Life cycle costing (LCC) helps the professional in the process of selecting among competing design alternatives and in delivering designs with the lowest possible total ownership cost. Although several researchers have defined distinct steps or phases in the life cycle costing methodology, Dell'Isola gives a more comprehensive approach towards LCC. He divides LCC analysis into four distinct sets of work elements which can be summarized as follows:

1. Identification Phase : Selection of Study Area
2. Development Phase : Selection of Design Alternatives
3. Evaluation Phase : Evaluation of Design Alternatives
4. Selection Phase : Selection of Alternatives

2.4.1 Identification of Study Area

It is important to identify the areas of study that pose the greatest potential savings for the entire project while reducing time and effort. In both private and public sectors, the owners of a construction project have the decision of establishing the criteria under which their facility will be planned, designed, and constructed. The governing policies raised by the administrative procedures may influence the analysis or will make it difficult to control (Coullahan, 1996).

2.4.2 Selection of Design Alternatives

This stage involves the development and proposal of several design alternatives that will be used in the evaluation phase. During this stage, several members of the LCC study group should participate in a creative effort in order to develop alternative design solutions. There are two common approaches in problem solving: the analytical approach that proceeds through structured steps involving evaluation and mathematical manipulation, and the creative approach which involves a mental process in which new ideas are generated based on combining and recombining past experiences. Among the techniques that are used to promote the creative approach are brainstorming technique, check listing, and the Gordan Technique.

In *The Brainstorming Technique* , which is most commonly used, the designer is encouraged to provide more solutions to problems. It simply consists of four to six people sitting together and producing ideas designed to solve a specific problem. The group will be more efficient as the number increases. Evaluation of ideas will only be allowed after the discussion so as to prevent the death of ideas. Some specific rules that should take place in brainstorming include :

Rule out criticism

Create a large number of ideas

Seek a large number of solutions

Watch for the possibility to combine or recombine ideas

The group should be selected to represent different background (Dell'Isola, 1995).

2.4.3 Evolution of Design Alternatives

The evaluation of different alternatives is an important step that leads to the best solution. This can be achieved through two main steps: the total life cycle cost of those alternatives are calculated, and then a weighted evaluation is performed. In order to organize the calculation process a general purpose LCC form is developed. The developed form is comprised of four main sections: capital cost, future expenditure, annual cost, and the sum of the present worth of LCC. The general purpose form is normally used when comparing individual components or parts of a facility, as shown in figure 2.5. Several forms have been developed to analyze an entire project in more detail. These forms are developed in accordance with the cost structure and are organized into six major categories: structural, architectural, mechanical, electrical, equipment, and site work..

Weighted evaluation is a method that makes evaluation of alternatives based on non- monetary benefits such as aesthetics, safety and expansion potential. In general, weighted evaluation will be considered in two cases:

1 Whether Life Cycle Costs for two or more alternatives are equal.

2. Whether the effect of uncertainty is so significant that no alternative clearly represents the best option.

Weighted Evaluation consists of two sequential steps: the weighted criteria and matrix analysis, as shown on figure 2.6. The criteria that have significant impact shall only be tested in the criteria weighting part.

Life Cycle Cost Analysis
General Purpose Work Sheet

Study Title: _____
Discount Rate: _____ Date: _____
Life Cycle (Years): _____ Present Time: _____

		Alternative 1 Describe:		Alternative 2 Describe:	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
Initial/Collateral Costs	Initial/Collateral Costs				
	A. _____				
	B. _____				
	C. _____				
	D. _____				
	E. _____				
	F. _____				
	Total Initial/Collateral Costs				
	Initial Cost PW Difference				
Replacement/Salvage Costs	Replacement/Salvage (Single Expenditure) — Year — PW Factor				
	A. _____				
	B. _____				
	C. _____				
	D. _____				
	E. _____				
	F. _____				
	Total Replacement/Salvage Costs				
Annual Costs	Annual Costs — Disc. Annual Rate — PWA or Annual				
	A. _____				
	B. _____				
	C. _____				
	D. _____				
	E. _____				
	F. _____				
	Total Annual Costs				
LCC	Total Life Cycle Costs (Present Worth)				
	Life Cycle Cost PW Difference				
	Discounted Payback				Years
	Total Life Cycle Costs (Annualized) — PP Factor		Per Year		Per Year

PW=Present Worth PWA=Present Worth of Annuity PP=Periodic Payment

Figure 2-5 : General Purpose Form (Dell'Isola,1995)

After listing the criteria, a letter of the alphabet is assigned to each and a degree of importance is then established for each criterion by pair comparison. The ranking is as follows:

- Major preference 4
- Medium preference 3
- Minor preference 2
- Slight or no preference 1.

When it happens that two alternatives have an equal degree of importance, both will be drawn in the scoring matrix given each one point. On the other hand, when one criteria is more important that the other, a degree of preference will be given in the criteria scoring matrix. When all comparative evaluations are made, the raw score for each criteria is totaled by adding the value assigned for each letters in the criteria scoring matrix.

The raw scores are then converted to a scale 0-10 under the weighted column with 10 being assigned to the criteria with the highest raw scores and the others are adjusted accordingly. In case the weights developed are too closely grouped or are too far apart or if a particular criteria didn't receive any score, but it is important, the score should be adjusted to reflect the properly defined score. Once the criteria weighting process is completed, the criteria and weights developed are used to evaluate the alternatives against the criteria to select the best alternative. The criteria and weights are put into the analysis matrix format as well as the alternatives. After that the primary criteria and the alternatives are evaluated against each other and ranked as follows: Ex-

cellent 5; Very Good 4; Good 3; Fair 2 and Poor 1. A proper rank is assigned for each alternative compared with other alternatives indexed in the same criteria. Then the rank of each alternative is multiplied by the weight of each criterion and the total is entered through the upper half of each loss. Finally the total score of each alternative is added up and entered into the total. The alternative having the highest total points is considered the best alternative (USGSA,1978).

Weighted Evaluation

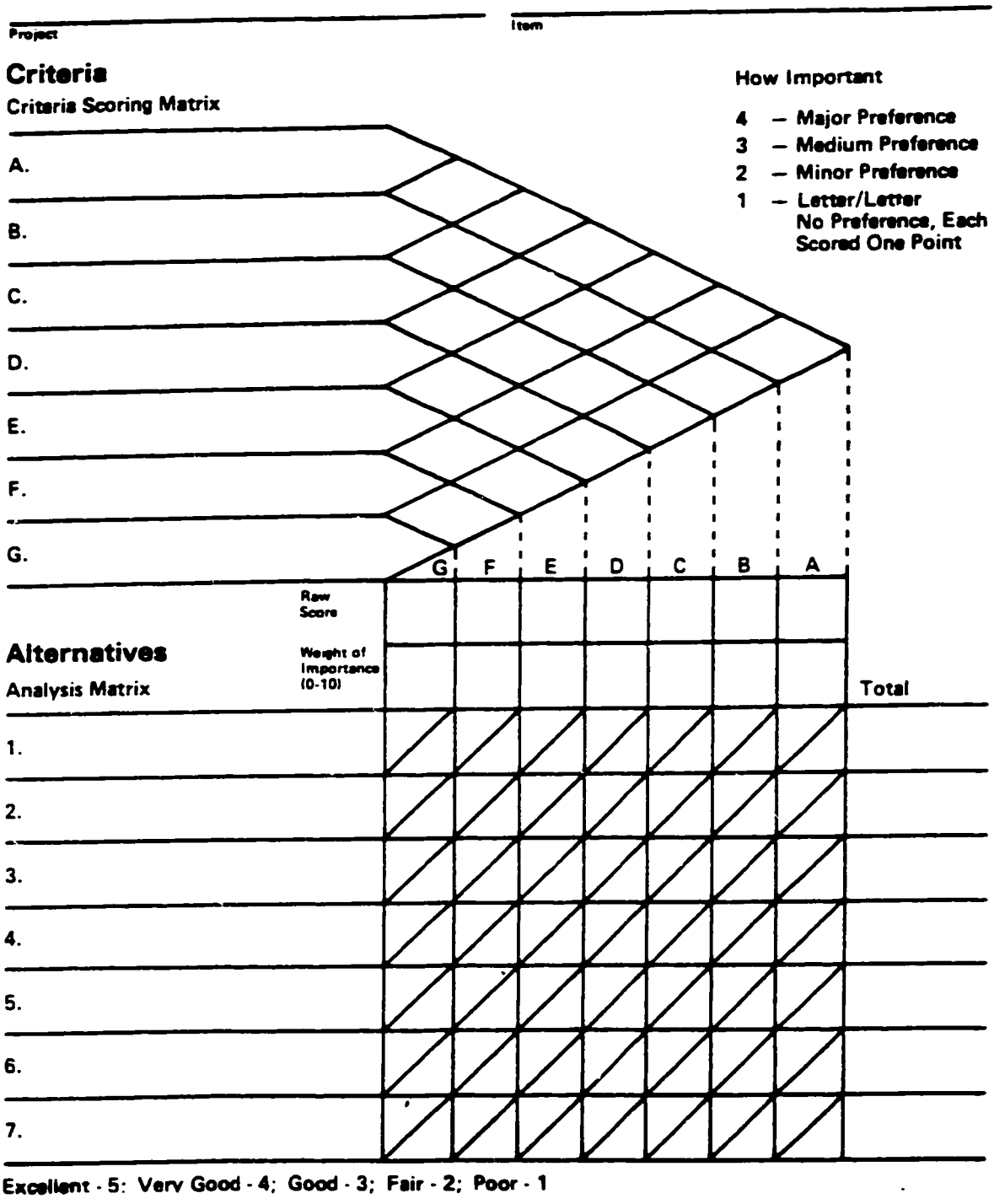


Figure 2-6 : Weighted Evaluation (Dell'Isola ,1995)

2.4.4 Selection of Alternatives

The selection of alternatives consists of two parts :

1. Dealing with uncertainty through risk assessment.
2. Assigning economic ranking to the alternatives.

First: Risk Assessment

There are two types of uncertainties: alternative independent uncertainties and alternative dependent uncertainties.

a) Alternative Independent Uncertainties: These include estimates of future inflation rates and assumptions and can be controlled by using a discount rate that is greater than the rate that would be used in the absence of uncertainty.

b) Alternatives Dependent Uncertainties :

Some of the alternatives that produce uncertainties are as follows:

1. Differential escalating rates
2. Technological change or obsolescence
3. Cost estimate accuracy
4. Useful life
5. Physical failure

There are two techniques commonly used to account for the effects of uncertainties, namely : Confidence Index and Sensitivity Analysis.

1. Confidence Index

As mentioned earlier the purpose of implementing CI is to judge whether the results of LCCA can be considered conclusive or not. The input data for alternatives (usually with the lowest and next lowest computed LCC's) are analyzed to determine whether there is a clear-cut probability that the alternatives with lower computed LCC will in fact have the lowest LCC. For design economics, this is considered clear-cut if it is more than 0.67. The CI approach should be considered valid when:

1. The high and low 90 percent estimates are obtained at the same time and from the same source or sources at the best estimate and considered to represent knowledge judgment rather than guesses.

2. The differences between PW of the best estimate for each cost and PW of high and low 90 percent estimates for that cost are within 25% of each other .

CI can be found by dividing the difference between the best estimates of both alternatives by the square root of sums of squares of all items of both alternatives. If the CI is less than or equal to 0.15, it will be considered as low confidence (i.e. in 3 out of 5 cases); the alternative with lower LCC will incur lower actual cost. If the CI is between 0.15 and 0.25, it will be considered as medium confidence (i.e. in 9 or 10 out of 15 cases) an alternative with lower LCC will incur lower actual cost. If the CI is greater than or equal to 0.25, high confidence will be assigned (i.e. two out of three cases) ; the alternative

with lower LCC will incur lower actual cost. A general form for computing confidence index ($\bar{CI}$) is shown in figure B-1 in appendix B (Dell'Isola,1995).

2. Sensitivity Analysis Approach

The sensitivity analysis approach to uncertainty, like the CI approach, is used to categorize the properties of two alternatives. The alternative with the lower CI will in fact have the lower LCC. This probability is considered conclusive if it is about 0.67 or more. The sensitivity analysis is approximated through (1) judgment, (2) the results of sensitivity analysis and (3) and the computed break-even point. Sensitivity analysis is used for determining how the value of one parameter is affected by variations in the value of a second parameter on which it depends. They are often called output and input parameters. The method is useful when the notation between the two parameters can't be expressed in closed form. It involves (1) the assignment of several reasonable values to the input parameters, (2) the computation of the output parameter that corresponds to each input parameter value, and (3) the analysis of pairs of values that result from the application of the method. A sensitivity break-even analysis form is shown in fig. B-2, appendix B (Dell'isola,1995).

Second : Ranking Selection

The important final step in LCCA is the assignment of economic ranking to the design alternatives. The alternative will be most economical when it considers all factors and it will be assigned the highest ranking.

Constraints on resources and programs

There are some constraints on resources as well as programs that will affect the complete analysis of LCC as shown in figure 2.7 (Bishop,1984).

Four categories have been generated with regard to the application of LCC: *The first case* occurs when both resources and programs are not constraints . In this case the design team have both time and fees to follow the iterative procedures to achieve the efficient allocation of resources in the long term and time will be available to select the best model for maintenance and services.

The second case occurs when programs, but not the resources, are constraints. This is an exceptional case in that there may not be any opportunity to explore the lengthy procedures of life cycle costing as in the case of urgent defense projects . *The third case* occurs when resources, but not programs, are constraints and is applied where the program can be adjusted to meet the budget. This could be done by reducing the number of contracts that have a life cycle cost exceeding the budget program. *The fourth case* occurs when both programs and budget are constrained. In this case, the comparison will be between elements as well as solutions for the same elements. Every effort should be made to include the initial cost within the budget, and brainstorming and remodeling will be used to identify the preferred strategy (Bishop,1984). The four categories are demonstrated in figure 2-7.

Resources / Programs	Not Constrained	Constrained
Not Constrained	Exceptional - e.g. programs of prestige projects such as embassies; single prestige projects e.g. headquarters of multi-national organizations	Typically programs of projects which may be adjusted to satisfy budgets e.g. bank or store refurbishment, highway or prison programs.
Constrained	Exceptional programs such as defense projects in times of crisis.	Most single projects and many programs e.g. private housing, public sector programs to meet statutory requirements (the former schools programs) most industrial and commercial development.

Figure 2-7 : Constraints in Resources and Programs in LCC Application (Bishop, 1984)

LIFE CYCLE COSTING EFFECTIVENESS

David H. Picken has related the effectiveness of LCC to the appropriate use as shown in figure 2.8. He characterized the low level of application which comes through simple education, training, and experience of the designer and he describe it as "Intuition Approach". The application of this level normally leads to dangerous territory because it dose not relay on accurate data. The medium and high levels of application described by having huge amount of data available in tables and records (Picken, 1987).

Level of Life Cycle Costing	Low	Medium	High
Characteristics Procedure	Undocumented	Informal - analysis not usually available to client	Formal - comprehensive report for client; presents and analysis alternatives
Data Source	Institution	Ad hoc (Limited In-house records data sought as required)	Tables, monthly reports of running costs. CIS (in UK, BOMA (in USA)
Benefits to Designers	Cheap (No extra man-power)	Confined to areas in need of analysis. Enhances selection procedures Contributes to development of services	Exposes shortcomings in design. Exposes logistical procedures of production. Allows reasoned consideration of several alternatives
Benefits to Financial Advisers	Cheap Maintains status quo of current professional status.	Additional expense low. Enhances comparative advice given to designers	Opens up new line of service. Enhances status in client's eyes.
Benefits to Client			
I) Cost to implernent LCC	Cheap	Still cheap possibly.	Expensive
ii) Building/Design Economics	Low	Much improved broader based decisions	High- if real time decisions model for Life Cycle Cost Management and Analysis.

Figure 2-8 Use Levels of Life Cycle Costing and their Character (Picken,1987)

2.5 PROBLEMS OF APPLICATION MANAGEMENT OF LCC

Although the Life Cycle Costing has received considerable attention in the past few years, the progress in application of life cycle cost ,as an aid to analyze the economic impact of various alternative design decisions in construction, has been steady although uninspired due to various problems. The researcher has identified twenty-six problems and classified them by source into five groups. A pilot study has been conducted to test the clarity of the problems and add others if any.

Pilot Study

The list of problems identified by the researcher was reviewed by five professionals in construction engineering. The review resulted in the fol lowing :

- Some problems were restated to be self-explained.
- Five more problems were added.

Accordingly a final list of problems was prepared and respondents were asked to check the rate of the problem as per its severity of application in agencies or firms. Problem ratings form the last portion of the questionnaire. Problems were categorized in accordance with the following five sections:

- Unfamiliarity Problems
- Data Problems
- Procedure Problems

- Management Problems
- Cost Problems

First: Unfamiliarity Problems

Unfamiliarity of Design to Cost Concept

Design to cost is a management concept used to control products of LCC by establishing cost goals in the acquisition process (AFMC, 1995). The design to cost concept considers cost as a design parameter similar to performance parameters. For every proposed facility there are certain minimum performance parameters that must be achieved or the building will not satisfy the owner's requirements and therefore should not be constructed. There is also a maximum cost ceiling that must not be exceeded or the facility will not be affordable economically. These limits shown on Fig. 2.9 fix the area within which a range of acceptable design solutions fall (Ahmad,1995).

Cost Ceiling

Range of Acceptable Solutions

Minimum Performance Criteria

Figure 2-9:Cost and Performance Limits in Design to Cost (Ahmad,1995)

Lack of Knowledge of Concept.

Although many clients and most public sector clients have become aware of the technique of life cycle costing and investment appraisal and most of them are increasingly calling consultants to offer such services to some of their project, others don't know that there is a future impact to this invest - ment. Accordingly, the substandard expenditures funds for design and construction should be made by a building's owner in anticipation of the shelter and services that the building will provide to people (Coullahan , 1996).

Unknown Relation Between Initial Cost and Running Cost

Some materials are durable and repay their high initial costs; others may be selected because their initial costs must meet budget limitations. Designers and owners of buildings have to recognize that there are some choices and trade-off between initial costs and recurring O&M costs. Decisions about a building's design, construction, operation, and maintenance can be made so that the building performs well over a specified period of time and the total of all costs incurred over that period will be minimized (Coullahan, 1996).

Unavailability of Satisfactory References

Due to a shortage of technical papers published on the subject of LCC, the concept tends not to be well known by most people in the construction industry. A greater availability of references to LCC could be an effective way to introduce the life cycle cost concept to firms and agencies.

Second: Data Problems

LCC is heavily dependent on data. The data used should be for buildings that have been completed and it should include all types of data such as cost, performance, occupancy and general description. Because of difficulties in assembling reliable data, life cycle cost has been regarded by many LCC consultants as being difficult to implement. In the absence of good information systems maintained by clients, the collection of data could be tedious and then the designer must draw upon any available published sources (Brandon,1992).

Unavailability of Capital Cost Data

This involves all data associated with the development of the facility and includes data related to fees, site, and other construction costs. These costs are normally developed on the basis of available data from the standard estimation sources, staff cost estimates, the architect, engineer, consultants, or construction manager (Dell'Isola,1995).

Unavailability of Maintenance Data

Maintenance data includes all data associated with the maintenance of the facility in use including regular repair, predictive maintenance, and annual maintenance costs. Maintenance data is the most difficult to forecast or estimate due to the fact that major expenditures on repair are normally assigned as a result of failure of tracking facilities or bad ownership rather than of overall scheduled aging (Preiser ,1989).

Unavailability of Operational Data

Operational data includes all data associated with operating the facility such as fuel, salaries of operators and energy costs. Operation data can't be varied by client policy as building maintenance can. This is because fuel consumption, staff requirements and other operating expenses of different systems can be calculated more accurately (Preiser,1989). However, complexity will be faced in cases where the scope of mechanical services, for example, is dependent upon the configuration of the building, such as a heat extraction system which might be necessary for a multi-story building that has a very low wall/floor area ratio. This has to be taken into consideration in carrying out a structural cost comparison.

Unavailability of Discount Or Interest Rate Data

The interest rate incorporates both time and value of money whereas the discount rate will be extracted from inflation. Choosing the appropriate discount rate will depend upon the type of client, his objectives and financial constraints. In most cases, there are some guides that could indicate the appropriate discount rate. It is not sufficient to request last year's budget plus a percentage to cover the inflation and interest rate.

Unavailability of Life Time Data

The choice of components depends on building functions and building life. Examination of LCC options will lead to the economic worth of options against the life of the investment. People engaged in life cycle cost planning will need to consult their clients and their clients' other professional advisors,

such as accountants, in relation to the "life of investment" for any particular commission (Brandon ,1992).

Large Volume of Data Needed

Life cycle cost technique is reorganized to involve the manipulation of a large amount of data (Brandon,1992). The data has to be filtered to obtain an enormous amount of information. The information derived from this data is used as an input for making an equally large number of decisions (Kabbani, 1996).

Unavailability of Standard Method for Collecting and Recording of Data

It is an essential task for the majority of property owners to contribute to the store of information. The major difficulty with this data is that it isn't kept in enough detail to enable the identification of individual components and the life of components (Preiser,1989). This is due to the lack of budget required to have measurable performance criteria. A successful, valid budget should also be based on hard data which clearly supports the functional objectives and is capable of withstanding critical analysis (Coullahan, 1996).

Unavailability of Data Base Management System

Because LCC requires the manipulation of large amounts of data, it is essential to construct a data base management system. A comprehensive data base includes building identification numbers, functions, size of the facility in square feet, age of the facility, the specific project data (scope and estimated cost) for contract work (Coallahan,1996).

Third : Procedure Problems

Unreliability of Decision Taken

The decisions or assumptions that have to be made in any life cycle cost exercise are : the life of the investment, discount rate, and residual value at the end of the project.

Lack of Integrity of Forecast

LCC should be used as an integral part of the design process in order for building owners to become aware of the likely cost of adopting a particular design option in terms of capital cost, whole LCC, and short term cash flow forecast (Brandon ,1992). This can be accomplished if data can be expressed in the form of what could happen, what should happen and what did happen (Flanagan,1989).

The Majority of LCC Calculations Involve Uncertainty

The decision is said to be uncertain if it has several possible outcomes. Similarly, the future behavior of materials, mechanical and electrical systems are uncertain depending on the future use of the building and the financial and economic conditions that influence the relationship between present and future cost.

Unavailability of Qualified Staff

The availability of qualified staff who can identify indirect cost as weil as direct cost, and have the potential to make the design and operating decisions, is very important to LCC (Gess , 1994). A quantity surveyor is likely to be the

most suitable person performing LCC, because he has the ability to cover all phases of LCC, including a selection study, generating of alternatives, and design evaluation, that will help in providing good results (Brandon ,1992).

Unavailability of Qualified Consultants

The availability of qualified consultants who have qualified staff could help in performing LCC. These consultants should be equipped with standard format and data and should have good access to suppliers and designers in order to produce good decisions.

Fourth: Management Problems

Un-acceptance of the Concept

Those people who don't accept the concept don't want to move from the short term gain concept into long term investment and consider buildings as a short term project. They refuse to consider that buildings are long term investments, in that they will incur running costs throughout their life which can't be ignored (Flanagan, 1989). Investors have to believe that the forecasting of future building expenses and prediction of events are better than facing future difficulties and liabilities.

Government Non-Enforcement

Some agencies or firms simply will not carry out any system unless it has been mandated by government and most of them consider the design job as a routine job that does not have any room for improvement or introduction of

good techniques. By introducing LCC, government agencies will not accept the design of any facility unless they are satisfied with the LCC analysis. The department in consultation with the associated public agencies, could provide guidelines to administer the LCC and define a procedure and method for performance of LCC analysis to promote the selection of low LCC alternatives.

Management (Client) Pressure to Meet Time Budget Limit

Budget limitations on construction resources can obstruct the complete analysis of LCC to search for alternatives. The application of LCC is always being pressured by management to meet design and cost targets (Brandon,1992). The limitations of initial cost will preclude the implementation of various economic life cycle cost alternatives.

Management (Client) Pressure to Meet Time Deadline on Design

Pressure in design stages may result in neglecting to perform a complete analysis and reduce the effort to develop feasible alternatives.

Unclear Benefits of LCC to Management (Client)

An unclear knowledge of the benefits that LCC could provide to clients can obstruct its application. LCC can provide many benefits, such as support for maintenance and operating budget, comparison of alternatives, planning, etc. The designer must ensure that in presenting his report to clients, he has given the correct level of detail upon which a management decision will be made. The level of detail given to a particular client will depend upon the type of client involved and his specific requirements.

Improper Planning and Control Management Tasks at Different LCC Stages

Although the concept of LCC is used by some industries in U.S., still the cost goals are not achieved due to lack of proper planning and control of management tasks at different stages of Life Cycle Cost. It is important to ensure that the effort devoted to data collection, evaluation, and documented study results in appropriate planning and control, including funding, the allocation of personnel, and monitoring resources which is critical to the success of Life Cycle Costing.

Fifth : Cost Problems

Cost to be paid for consultants to conduct LCC

In order for LCC to be conducted efficiently, the designer should be paid for his effort.

Cost to be Paid for Collection of Data

Data collection is not free. Accordingly, there are costs for collecting and analyzing data that has to be considered in LCC.

Difficulties in Defining Cost Elements

The LCC management system is very important at this stage in the sense that LCCM can be extended by clearly defining each of element of a system, each of the steps in the process and each stage in the LCC and then identifying each of the cost elements within a defined scope (Gess ,1994).

CHAPTER 3
SURVEY METHODOLOGY

The researcher has tried to determine the extent of application of LCC on construction projects and explore problems that hamper the application. First, the researcher was introduced to a LCC course in Riyadh. The course was presented by the well known LCC consultant Alphonse. J. Dell'Isola. Throughout the course, a specific LCC analysis done on some local private projects was discussed. The course was attended by a number of private companies as well as government agencies .

A previous study done on *The Application of Value Engineering on Public Construction Projects in Saudi Arabia,* in June, 1987, concluded that only the General Directorate of Military Works (GDMW) were using V.E formally (Al-Sughaiyer,1987). Accordingly, the researcher has approached them to explore the extent of application of LCC since it represents an important part of a value engineering study. The researcher met with Issam Kabbani from GDMW, who was responsible for introducing LCC to the GDMW engineers and has published many articles about the LCC concept. The researcher also found that a new administration for value engineering has been created in 1995 as part of the General Administration of Planning and Budgeting in the Ministry of Municipal and Rural Affairs (MMRA). Its aim is to transfer and apply value engineering to ministry projects. The researcher met with Hamoud Al - Salmi , managing director of Budgeting and Planning at MMRA.

During the course of discussion in both departments, it was found that LCC is being used only as a part of value engineering studies. The researcher does not know if LCC is being used by any other agency either as part of value engineering or as subject by itself. This study hopes to explore the matter and determine obstacles to Life Cycle Cos ting applications.

In the light of these facts, the researcher has developed a questionnaire to cover two groups:

1. Government Agencies
2. Consulting Offices

Government agencies represent public construction project owners who have the authority to request the application of LCC on their projects. Consulting firms also play an important part in providing technical services to the government agencies.

3.1 Design of Questionnaires :

First : The Government Agency Questionnaire is divided into three parts :

Part I : *Respondents Description.*

Part II : *Application of Life Cycle Costing.*

Part III : *Problems in The Application of Life Cycle Costing.*

Part I, (questions describing the respondent), investigates job title, field of experience, years of experience and qualification. *Part II, (questions related to the application of LCC),* starts with introductory questions regarding knowledge of the concept, whether LCC is being applied by the agency or not, and the economic analysis used by the agency. A brief explanation of the

concept of LCC was given to those who were not aware of the concept in Appendix A of the questionnaire. The respondents were divided into two groups:

Those who apply Life Cycle Costing.

Those who do not apply Life Cycle Costing.

Those who do not apply LCC were asked to stop at this stage and those who apply LCC were asked to answer the remaining questions. The remaining part concerns the formal application of LCC. So, it is supposed to be answered by those who apply the formal LCC only. Remaining questions investigate the extent of LCC application, experience in using LCC, purpose of utilizing LCC, sources of data used to calculate LCC, size of staff, future expansion in LCC application, and who is performing LCC studies for government. As a last question, respondents were asked to give their opinion on enforcement of LCC in government projects.

Finally, *Part III,(problems related to application and directed to respondents who apply LCC formally, since they are more familiar with the concept),*checks the severity of different problems in the application and ask for additional problems encountered if any. Rating ranges from very severe, severe, somewhat severe, somewhat not severe and not severe. As a last question in the questionnaire, respondents were asked to give any additional comments .

Second : The Consulting Office Questionnaire is divided into three parts:

Part I : *Respondents Description..*

Part II : *Application of Life Cycle Costing.*

Part III : *Problems in The Application of Life Cycle Costing.*

Part I,(questions describing the respondent), investigate job title, field of experience, years of experience, and qualifications. *Part II, (questions about the application of LCC)* starts with preliminary questions regarding firm size, knowledge of the agency about LCC, whether or not LCC is being applied, and the economic analysis being used by the agency. A brief explanation of the concept of LCC was given to those who were not aware of the concept in Appendix A of the questionnaire. The respondents were divided into two groups:

Those who apply Life Cycle Costing.

Those who do not apply Life Cycle Costing.

Those who do not apply LCC were asked to stop at this stage while those who apply LCC were asked to answer all of the remaining questions. The remaining part is concerned with the formal application of LCC. So, it is supposed to be answered by those who apply the formal LCC only. Remaining questions investigate the extent of LCC application, experience in using LCC, the purpose of utilizing LCC, source of data used to calculate LCC, size of staff, and future expansion in LCC application. As a last question, respondents were asked to give their opinion on enforcement of LCC in government projects.

Finally, *Part III, (problems of application of LCC and directed to respondents who apply LCC formally, since they are more familiar with the concept),* checks the severity of different problems in the application and ask for additional problems encountered if any. Rating ranges from very severe, severe, somewhat severe, somewhat not severe and not severe. As a last ques-

tion in the questionnaire, respondents were asked to give any additional comments .

3.2 Sampling:

Government Agencies: The population was defined to be all of the government departments that have the authority for requesting and/or supervising the execution of public construction projects. The government annual budget allocations were used as a source for identifying these departments. The General Department of a Statistics in the Ministry of Finance and National Economy issues Statistical Year Book which contains, among other statistics, the Government Budget. Issue number thirty of this book, 1995, was used to produce the list of Government Departments which satisfy the above definition. They were a total of 45 agencies and they were listed in the order they appear in the budget allocations. The Government Agencies List is in Appendix D. They were all examined since the population size is small and no sampling scheme was used.

Consulting Offices: Consulting Offices were defined as those Consulting Offices in the kingdom which are listed in the Directory of Consulting and Engineering Offices published in 1411 (1991) and updated in 1416 (1996). There are 250 consulting offices located in different parts of the kingdom. The sample size for this population group was determined using the following formula:

$$n = \frac{\left(t \cdot s / d\right)^2}{1 + \frac{\left(t \cdot s / d\right)^2}{N}}$$

where:

n : Sample size to be found

N: Sample population size (250).

$t: t_{\frac{\alpha}{2}}$ is the abscissa of the normal curve that cuts off an area of $\alpha = 0.5$ at the tail.

$t = 1.960$

d : the expected error in the estimate.

The amount of accuracy $(1- \alpha)\% = 0.05$ for 95% confidence interval.

s : $s = \sqrt{pq}$

p : is the proportion to the characteristic under investigation. The maximum of $p = \frac{1}{2}.q = 1 - \frac{1}{2} = \frac{1}{2}$

Therefore, the sample size is calculated through the iteration process to determine a reasonable sample size for the survey as follows:

$$n = \frac{(\frac{t}{d}s)^2}{(1 + (\frac{t}{d}s)^2 / N)}$$

$$n = \frac{(1.96 * \frac{0.5}{.05})^2}{(1 + (1.96 * \frac{0.5}{.05})^2 / 250} = 151.44$$

$$n = \frac{151.44}{(1 + 151.44 / 250)} = 94.3$$

$n = 68.48$

$n = 53.75$

$n = 44.23$

$n = 37.65$

$n = 32.72$

$n = 28.93$

$n = 25.92$

$n = 23.48$

since the difference becomse smaller, the sample size is 24 consulting office.

3.3 Data Collection :

Necessary copies of the questionnaire were mailed on 22nd of May 1996 to both government agencies and consulting offices. A total of only fifty filled questionnaires were returned within three months, received from both government and consulting firms. After that a follow-up letter was sent to those who did not respond, reminding them about the questionnaire and asking them for a response . By the 5th of November 1996 , there was a total of sixty eight responses ; twenty-four responses were received from government agencies and forty-four responses were received from firms. The sixty-eight responses were used in the analysis. Although, the sample size needed in firms is only twenty-four responses, all responses received have been used for the analysis.

CHAPTER 4
RESULTS AND DISCUSSION

Introduction

The objective of the research as discussed earlier is to find the extent of use of Life Cycle Costing in construction projects, and to find problems that obstruct its application in the construction industry.

This chapter contains, mainly, the results related to Life Cycle Costing from the questionnaire sent to both government agencies and consulting offices.

Results and Analysis

The results of this study have been generated from 24 responses received from government agencies and 44 responses received from consulting offices to the questionnaire mailed to 45 government departments and organizations and 250 consulting offices. The data collected was analyzed and summarized by calculating frequencies, percentage, and severity index of problems. The discussion will be as per the following list:

4.1 Respondents Description

- Respondents Job Title.
- Respondents Experience.
- Respondents Qualification.

4.2 Life Cycle Cost Application

- Knowledge of the concept of LCC.
- Adopting the concept of LCC.
- Different economic analysis being used.

- Extent of LCC application.
- Introduction of LCC.
- Purpose of utilizing LCC.
- Sources of data used in LCC calculations.
- Size of LCC staff.
- LCC future expansion.
- Reference of parties performing LCC (directed to government agencies only).
- Enforcement of LCC for public construction projects.

4.3 Problems associated with the LCC applications.

4.3.1 Unfamiliarity Problems

- Non-Familiarization of design to cost concept.
- Lack of knowledge of the concept.
- Unknown relation between initial cost and running cost.
- Unavailability of satisfactory references.

4.3.2 Data Problems

- Unavailability of capital cost data.
- Unavailability of maintenance cost data.
- Unavailability of operational cost data.
- Unavailability of interest rate data.
- Unavailability of life time data.
- Large volume of the data needed.

  Unavailability of standard method for collecting and recording of data.

- Unavailability of a data base management system.

4.3.3 LCC Procedure Problems

- Unreliability of decisions taken.
- Lack of integrity of the forecast.
- Majority of LCC calculations involve uncertainty.
- Unavailability of qualified staff.
- Unavailability of qualified consultants.

4.3.4 Management Problems

- Non-acceptance of the concept.
- Government non-enforcement.
- Client or management pressure to meet capital budget limit.
- Client or management pressure to meet design deadline.
- Unclear benefits of LCC to client or management.
- Improper planning and control of management tasks at different LCC stages.

4.3.5 Cost Problems

- Cost to be paid to a consultant to conduct LCC.
- Cost to be paid for collecting and analyzing the data.
- Difficulties in identifying cost components.

4.1 Respondents Description :

This section presents the description of respondents to the questionnaire including 24 government agencies responsible for execution of public construction projects and 44 consulting offices that provide the technical services to the government agencies. Respondents were spread all over the kingdom.

The questionnaire was answered by project engineers, designers, project managers and planning managers who had long experience in construction projects.

It was found that 50% of government respondents have experience of more than 10 years and 92 % of them were qualified by experience and training, as shown on table 4.2 and 4.3

Table 4.1 Job Title of Government Respondents

RESPONDENTS POSITION	FREQUENCY (# OF RESP)	PERCENT (%)
Project Engineer	5	21
Cost Engineer	1	4
Maintenance Engineer	0	0
Design Engineer	5	21
Others	13	54
	n=24	

Table 4.2 Experience of Government Respondents

EXPERIENCE (YEARS)	FREQUENCY (# OF RESP)	PERCENT (%)
< 3	0	0
3 --- 5	3	13
6 --- 10	9	38
> 10	12	50
Others	0	0
	n=24	

Table 4.3 Qualification of Government Respondents

Qualification	FREQUENCY (# OF RESP)	PERCENT (%)
Experience	22	79
Engineering Degree	0	0
Unacademic Degree	1	4
On-Job Training	4	14
Others	1	4
	n=28	

Similarly, it was found that 45 % of consulting offices respondents have experience of more than 10 years and 82% of them have an academic degree, as shown on table 4.5 and 4.6.

Table 4.4 Consulting Offices Respondents Job Titles

RESPONDENTS POSITION	FREQUENCY (# OF RESP)	PERCENT (%)
Project Engineer	17	39
Cost Engineer	0	0
Maintenance Engineer	0	0
Design Engineer	16	36
Others	11	25
	n=44	

Table 4.5 Consulting Offices Respondents Experience

EXPERIENCE (YEARS)	FREQUENCY (# OF RESP)	PERCENT (%)
< 3	0	0
3 — 5	8	18
6 — 10	10	23
> 10	20	45
Others	6	14
	n=44	

Table 4.6 Consulting Offices Respondents Qualification

Qualification	FREQUENCY (# OF RESP)	PERCENT (%)
Experience	8	18
Engineering Degree	36	82
Unacademic Degree	0	0
On -Job Training	0	0
Others	0	0
	n=44	

Firm size (directed to consulting firms only)

Table 4.7 indicates that the size of firms responding to the questionnaire are as follows: 14 of 44 (32%) representing small firms (less than 10 personnel), 16 of 44 (36 %) representing medium size firms (11-30 personnel), 7 of 44 (16 %) representing large firms (30-50 personnel) and 7 of 44 (16 %) representing very large firms (more than 50 personnel).

Table 4.7 Frequency and Percentage Firms Sizes

FIRM SIZE	FREQUENCY (# OF RESP)	PERCENT (%)
A. Less than 10 person (small)	14	32
B. Between 11 and 30 person (medium)	16	36
C. Between 31 and 50 person (large)	7	16
D. More than 50 (very large)	7	16
	n=44	

4.2 Life Cycle Cost Application

Knowledge of the concept

Table 4.8 indicated that the levels of knowledge of LCC in government agencies are as follows: all the 24 respondents (100%) knew about the concept. Among them, one respondent claimed that he knew the concept "very well", eight respondents claimed that they knew the concept "well", twelve respondents claimed that they knew the concept "somewhat" and three respondents claimed that they knew "little" of the concept.

Table 4.8 Frequencies and Percentage Levels of Knowledge in Government

LEVEL OF KNOWLEDGE	FREQUENCY (#OF RESP)	PERCENT
A. Very well	1	4
B. Well	8	33
C. Somewhat	12	50
D. Littie	3	13
E. None	0	0
	n=24	

Table 4.9 Frequencies and Percentage Levels of Knowledge in Firms

LEVEL OF KNOWLEDGE	FREQUENCY (# OF RESP)	PERCENT (%)
A. Very well	6	14
B. Well	16	36
C. Somewhat	12	27
D. Little	5	11
E. None	5	11
	n=44	

Table 4.9 indicates that 89% (39 of 44) of respondents knew about the concept. Among them, six respondents claimed that they knew the concept "very well", sixteen knew the concept "well", twelve knew the concept "somewhat" and five knew "little" of the concept.

Adopting the concept of LCC.

This part of the questionnaire will investigate the levels of adopting the concept of LCC. In this case, either the logic or the formal application of LCC are considered.

Table 4.10 indicates that the levels of adopting LCC in government agencies are as follows: out of 24 respondents, 16 (67 %) claimed that they adopt LCC. Among those who claimed the adoption of the concept, four respondents used LCC "often", six used LCC "sometimes", and another six used "little" of LCC.

Table 4.10 Frequencies and Percentage Levels of Adopting LCC in Gov - ernment

LEVEL OFADOPTING	FREQUENCY (# OF RESP)	PERCENT (%)
A. Always	0	0
B. Often	4	17
C. Sometimes	6	25
D. Little	6	25
E. Never	8	33
	n=24	

Table 4.11 Frequencies and Percentage Levels of Adopting LCC in Firms

LEVEL OFADOPTING	FREQUENCY (# OF RESP)	PERCENT (%)
A. Always	3	7
B. Often	3	7
C. Sometimes	12	27
D. Little	16	36
E. Never	10	23
	n=44	

Table 4.11 indicates that LCC is being adopted by 77 % of consulting firms (34 of 44). Among those who claimed the adoption, three used LCC "always", another three used LCC "often", twelve used LCC " sometimes", and sixteen used "little" of LCC.

Other economic methods applied in construction projects

Table 4.12 indicated that the types of economic methods being used by government agencies are as follows: 44 % of respondents used present worth method (PW), 15 % of respondents used equivalent annual cost method (EUAC), 9 % of respondents used rate of return method (ROR), 6 % of respondents used pay back method (PB), 3 % of respondents used discounted pay back method (DPB) and 24% of respondents used other forms of analysis. The other forms of analysis include the followings:

- Analysis of expenditures to ensure budget limit is not exceeded.
- Feasibility study analysis that shows the essential future need in case of health type projects.
- The value engineering analysis indicating measures that lower project costs.
- The value engineering analysis indicating measures that shall be met in materials and equipment to minimize costs.
- Analysis of the present and future expenditures of any material or equipment to make sure that material and equipment could be maintained locally.
- Analysis that compares costs of renovation and rebuilding in case of renovation type projects.
- Analysis that indicates the assessment of the requirement and policies of management.
- General analysis that includes any type of project.

Table 4.12 Frequencies and Percentage of Economic Methods in Government

ECONOMIC METHOD	FREQUENCY (# RESP)	PERCENT (%)
A. Present Worth Method (PW)	15	44
B. Equivalent Annual Cost (EUAC)	5	15
C. Rate of Return (ROR)	3	9
D. Pay Back Period (PBP)	2	6
E. Discounted Pay Back Period (DPBP)	1	3
F. Others	8	24
	34	

Table 4.13 Frequencies and Percentage of Economic Methods in Firms

ECONOMIC METHOD	FREQUENCY (# RESP)	PERCENT (%)
A. Present Worth Method (PW)	19	38
B. Equivalent Annual Cost (EUAC)	6	12
C. Rate of Return (ROR)	5	10
D. Pay Back Period (PBP)	12	24
E. Discounted Pay Back Period (DPBP)	1	2
F. Others	7	14
	50	

Table 4.13 indicates that the types of economic methods used by consulting firms are as follows: 38 % of respondents used present worth method (PW), 12 % of respondents used equivalent annual cost method (EUAC), 10 % of respondents used rate of return method (ROR), 24 % of respondents used pay back method (PB), 2 % of respondents used discounted pay back method

(DPB) and 14 % of respondents used other economic analysis. Other economic analysis includes bill of quantity and others that were not specified.

Formal Application :

Responses to questions related to the formal application of life cycle cost - ing, which include all the remaining part of the questionnaire, indicate that only 11 government's respondents and 12 consulting firms' respondents have utilized the life cycle cost in its formal procedures. Others may have the intention to apply the logic but not in its formal application. By merging results of table 4.10 and 4.11, for level of adopting LCC in government and consulting firms, and responses to formal application questions, table 4.14 and table 4.15 can be constructed.

Table 4.14 indicates that 11 respondents (representing 46%) of government agencies have used LCC formally, 5 respondents (representing 21%) have used the non-formal LCC and 8 respondents (representing 23%) have not used LCC at all.

Table 4.14 Frequencies and Percentage Types of Application of LCC By Goverment

Type of Application	Frequency	Percent
Formal application	11	46
Non-Formal application	5	21
LCC is not applied	8	33
Total	n=24	

Table 4.15 Frequencies and Percentage Types of Application of LCC By Firms

Type of Application	Frequency	Percent
Formal application	12	27
Non-Formal application	22	50
LCC is not applied	10	23
Total	n=44	

Table 4.15 indicates that 12 respondents (representing 27 %) of consulting firms have used LCC formally, 22 respondents (representing 50 %) have used the non-formal application and 10 respondents (representing 23%) have not used LCC at all.

Previous statistics indicate the followings :

- Consulting firms have better knowledge of LCC than government, which is indicated by the fact that about 1/3 (37%) of government agencies know the concept "well" or better while 1/2 of firms know the concept "well" or better. This is due to the firm's experience or due to expatriate staff who have been introduced to the concept in their home countries.
- Although the concept of LCC is familiar to most engineers, the frequencies of using LCC by government agencies and firms are low which may be due to problems that make the application of the concept difficult.
- Present worth method (PW) and equivalent annual cost method (EUAC) are being used to accomplish a different economic purpose (other than LCC). Although there are 20 government's respondents and 25 firms' respondents using PW or EUAC, only 11 government respondents and 12

firm's respondents are using the formal LCC that involves computation of PW and EUAC.

- LCC is being applied by about $\frac{2}{3}$ of government agencies and ¾ of consulting firms.
- Among those who apply LCC, there are 68% of government respondents and 35 % of firms' respondents have used the formal procedures in application.

Extent of Application of Life Cycle Cost

Table 4.16 indicates that LCC is being applied by 60% of projects by 3 agencies (representing 27%), it is being applied by 40% of project by 2 agencies (representing 18%), it is being applied by 20% of projects in 6 agencies (representing 55%).

Table 4.16 Frequencies and Percentage Extents of Application of LCC By Goverment

EXTENT USE	FREQUENCY (# RESP)	PERCENT (%)
A. LCC is being applied in all projects	0	0
B. LCC is being applied in 80% of projects	0	0
C. LCC is being applied in 60% of projects	3	27
D. LCC is being applied in 40% of projects	2	18
E. LCC is being applied in 20% of projects	6	55
	11	

Table 4.17 Frequencies and Percentage Extent of Application of LCC By Firms

EXTENT USE	FREQUENCY (# RESP)	PERCENT (%)
A. LCC is being applied in all projects	1	8
B. LCC is being applied in 80% of projects	3	25
C. LCC is being applied in 60% of projects	3	25
D. LCC is being applied in 40% of projects	1	8
E. LCC is being applied in 20% of projects	4	33
	12	

Table 4.17 indicates that the extent of application of life cycle cost by consulting firms is as follows: It is being applied to all its projects by only one respondent (representing 8%) where it is being applied to projects related to plans and activities; it is being applied to 60% of projects by 3 respondents (representing 25); it is being applied to 40% of projects by one respondents (representing 8%) and it is being applied to 20% of projects by 4 respondents(33%).

Introduction of Life Cycle Costing

Tables 4.18 indicates that responses to introducing time of LCC in government agencies are as follows: 18 % of respondents (2 of 11) introduced LCC less than two years ago, 45 % of respondents (5 of 11) have introduced LCC during the last three to five years and 36 % of respondents (4 of 11) in troduced LCC more than ten years ago.

Table 4.18 Frequencies and Percentage of Introducing Times of LCC By Government

INTRODUCING TIME	FREQUENCY (# RESP)	PERCENT (%)
A. Since less than two years ago	2	18
B. Between three to five years	5	45
C. Between six to ten years	0	0
D. Since more than ten years ago	4	36
E. Other	0	0
	11	

Table 4.19 Frequencies and Percentage of Introducing Times of LCC By Firms

INTRODUCING TIME	FREQUENCY (# RESP)	PERCENT (%)
A. Since less than two years ago	4	33
B. Between three to five years	1	8
C. Between six to ten years	5	42
D. Since more than ten years ago	2	17
E. Other	0	0
	12	

Table 4.19 indicates that 33 % (4 of 12) of the consulting firms' respondents introduced the concept less than two years ago, 8 % of respondents (1 of 12) have introduced the concept during the last three to five years, 42 % of respondents (5 of 12) introduced the concept six to ten years ago, and 17% of respondents (2 of 12) have been using the concept for more than 10 years.

Forms of Utilizing Life Cycle Costing :

Table 4.20 indicates that the forms of utilizing LCC by government agencies are as follows : 13% of the respondents claimed that LCC is being used as part of V.E, 40% of respondents claimed that LCC is being used as a technique to choose between alternatives, 13 % of respondents claimed that LCC is being used as a technique to predict future costs, 27 % of respondents claimed that LCC is being used as a means for budgeting and, finally, 7 % of respondents claimed that LCC is being used in other forms. The other forms were not specified.

Table 4.20 Frequency and Percentage of Different Utilizing Forms of LCC By Government

UTILIZING FORMS	FREQUENCY (# of RESP.)	PERCENT (%)
A. As part of value engineering (V.E) analysis	2	13
B. As technique to compare alternatives	6	40
C. As technique to predict future costs	2	13
D. As a means for budgeting	4	27
E. Other	1	7
	15	

Table 4.21 Frequency and Percentage of Different Utilizing Forms of LCC By Firms

UTILIZING FORMS	FREQUENCY (# of RESP.)	PERCENT (%)
A. As part of value engineering (V.E) analysis	5	28
B. As technique to compare alternatives	5	28
C. As technique to predict future costs	5	28
D. As a means for budgeting	2	11
E. Other	1	6
	18	

Table 4.21 indicates that 27% of consulting firms claimed that LCC was being used as part of the V.E study, 27 % of respondents claimed that LCC was being used as a technique to choose between alternatives, 27 % of respondents also claimed that LCC was being used as a technique to predict future costs, 11% of respondents claimed that LCC was being used as a means for budgeting and 6 % of respondents claimed that LCC was being used in other forms. The other forms included feasibility studies for industrial projects .

Sources of LCC Data

Initial Cost Data

Table 4.22 indicates that responses to the sources of initial costs data for government agencies are as follows: 29 % of initial cost data is obtained through manufacturers and suppliers, 29% of initial cost data is obtained through predictive calculations, another 29 % of data is obtained through experience while 12 % of data comes through historical records.

Table 4.22 Frequency and Percentage of Sources of Initial Cost Data in Government

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	5	29
Predictive calculations	5	29
Experience	5	29
Historical records	2	12
Others	0	0
	17	

Table 4.23 Frequency and Percentage of Sources of Initial Cost Data in Firms

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	5	42
Predictive calculations	4	33
Experience	3	25
Historical records	0	0
Others	0	0
	12	

Table 4.23 indicates that responses of consulting firms to sources of initial cost data are as follows: 42 % of initial cost data (5 of 12) is obtained through manufacturers and suppliers, 33 % of initial cost data (4 of 12) is obtained through predictive calculations and 25 % of initial cost data (3 of 12) is obtained through historical records .

Maintenance Cost Data

Table 4.24 indicates that responses to the sources of maintenance data in government are as follows: 24 % of the data (4 of 16) is obtained through manufacturers and suppliers, 29 % of the data (5 of 16) is obtained through predictive calculations, 18 % of the data (3 of 18) is obtained through experience, 24 % of the data is obtained through historical records and 6 % of data is obtained through other sources. 'Other sources of data ' was derived from percentage of other costs.

Table 4.24 Frequency and Percentage of Sources of Maintenance Cost Data in Government

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	4	24
Predictive calculations	5	29
Experience	3	18
Historical records	4	24
Others	1	6
	17	

Table 4.25 Frequency and Percentage of Sources of Maintenance Cost Data in Firms

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	3	17
Predictive calculations	7	39
Experience	4	22
Historical records	4	22
Others	0	0
	18	

Table 4.25 indicates that responses of consulting firms to sources of maintenance cost data are as follows: 17 % of the data (3 of 18) is obtained through manufacturers and suppliers, 39 % of the data (7 of 18) is obtained through predictive calculations, 22 % of the data is obtained through experience , and finally 22.22 % of data is obtained from historical records.

Operational Cost Data

Table 4.26 indicates that responses of government agencies to the sources of operational cost data are as follows: 26 % of the data is obtained through manufacturers and suppliers, 32 % of the data is obtained through predictive calculations, 16 % of the data is obtained through experience, 21 % of the data is obtained through historical records and 5% of the data is obtained from other sources. In the other sources, data is calculated as percent of other costs.

Table 4.26 Frequency and Percentage of Sources of Operational Cost Data in Government

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	5	26
Predictive calculations	6	32
Experience	3	16
Historical records	4	21
Others	1	5
	19	

Table 4.27 Frequency and Percentage of Sources of Operational Cost Data in Firms

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	5	42
Predictive calculations	4	33
Experience	0	0
Historical records	3	25
Others	0	0
	12	

Table 4.27 indicates that responses of consulting firms to sources of operational cost data are as follows: 42 % of the data is obtained through manufacturers and suppliers, 33 % of the data is obtained through predictive calculations and only 25 % of the data is obtained through historical records.

Replacement costs Data

Table 4.28 indicates that responses to the sources of replacement cost data for government agencies are as follows: 27 % of the data is obtained from manufacturers and suppliers, 33 % of the data is obtained from predictive calculations, 20 % of the data is obtained through experience, 13 % of the data is obtained from historical records and 7 % of the data is obtained from other sources . Other sources is by percent of other costs.

Table 4.28 Frequency and Percentage of Sources of Replacement Cost Data in Government

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	4	27
Pedictive calculations	5	33
Experience	3	20
Historical records	2	13
Others	1	7
	15	

Table 4.29 Frequency and Percentage of Replacement Cost Data in Firm

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	5	36
Predictive calculations	2	14
Experience	5	36
Historical records	2	14
Others	0	0
	14	

Table 4.29 indicates that responses of consulting firms to sources of replacement cost data are as follows: 36 % of the data is obtained from manufacturers and suppliers, 14 % of the data is obtained from predictive calculations, 36 % of the data is obtained from experience and 14 % of the data is obtained from historical records.

Interest (Investment) Rate Data

Table 4.30 indicates that responses of government agencies to the sources of interest rate are as follows: 10 % of the data is obtained from manufacturers and suppliers, 40 % of the data is obtained though predictive calculations, 20 % of the data is obtained from experience, 10 % of the data is obtained from historical records and 20% of the data is obtained from other sources. The other sources include banks' records although it is sometimes ignored.

Table 4.30 Frequency and Percentage of Sources of Interest Rate Data in Government

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	1	10
Predictive calculations	4	40
Experience	2	20
Historical records	1	10
Others	2	20
	10	

Table 4.31 Frequency and Percentage of Sources of Interest Rate Data in Firms

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	1	8
Predictive calculations	6	50
Experience	2	17
Historical records	2	17
Others	1	8
	12	

Table 4.31 indicates that responses of consulting firms to sources of interest rate data are as follows: 8 % of the data is obtained from manufacturers and suppliers, 50 % of the data is obtained from predictive calculations, 17 % the data is obtained form experience, 17% of the data is obtained from historical records and 8 % of the data is obtained from other sources. 'Other sources ' were not specified.

Life Time Data

Table 4.32 indicates that government responses to the sources of life time data are as follows: 15 % of the data is obtained from manufacturers or suppliers, 23 % of the data is obtained from predictive calculations, 46 % of the data is obtained from experience, 8 % of the data is obtained from historical records and 8 % of the data is obtained from other unspecified sources.

Table 4.32 Frequency and Percentage of Sources of Life Time Data in Government

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	2	15
Predictive calculations	3	23
Experience	6	46
Historical records	1	8
Others	1	8
	13	

Table 4.33 Frequency and Percentage of Sources of Life Time Data in Firms

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	3	20
Pedictive calculations	2	13
Experience	9	60
Historical records	1	7
Others	0	0
	15	

Table 4.33 indicates that responses of consulting firms to sources of life time data are as follows: 20 % of the data is obtained from manufacturers or suppliers, 13 % of the data is obtained from predictive calculations, 60 % of the data is obtained from experience and only 7 % of the data is obtained from historical records.

Salvage Value Data

Table 4.34 indicates that government agencies responses to the source of salvage value data are as follows: 11 % of the data is obtained from manufacturers or suppliers, 22 % of the data is obtained from predictive calculations, 56 % of the data is obtained from experience and 11 % of the data is obtained from other sources.

Table 4.34 Frequency and Percentage of Sources of Salvage Cost Data in Government

SOURCES OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers , specialists and suppliers	1	11
Predictive calculations	2	22
Experience	5	56
Historical records	0	0
Others	1	11
	9	

Table 4.35 Frequency and Percentage of Sources of Salvage Cost Data in Firms

SOURCE OF DATA	FREQUENCY (# RESP.)	PERCENT (%)
Manufacturers . specialists and suppliers	3	20
Predictive calculations	2	13
Experience	9	60
Historical records	1	7
Others	0	0
	15	

Table 4.35 indicates that responses of consulting firms to sources of salvage value data are as follows: 20 % of the data is obtained from manufacturers and suppliers, 13 % of the data is obtained from predictive calculations, 60 % of the data is obtained from experience, and 7 % of data is obtained through historical records.

The extent of different sources of LCC data are presented in figure 4.1a and 4.1b.

Fig. 4.1a The Extent of Different Sources of LCC Data in Government

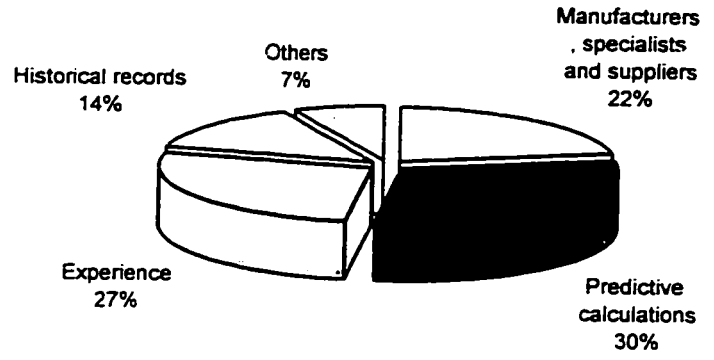
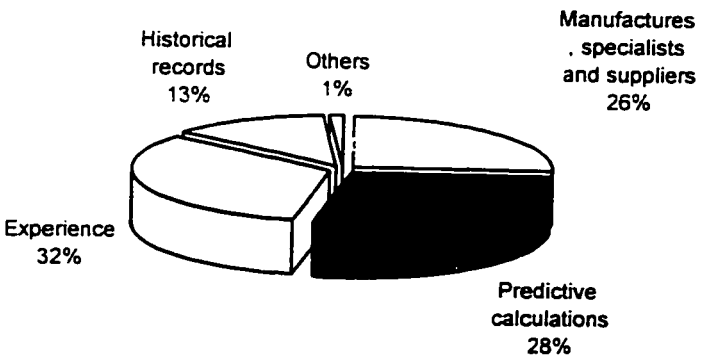


Fig.4.1b The Extent of Different Sources of LCC Data in Consulting Firms



The foregoing statistics indicate the following:

- The extent of application of LCC shows that it is not used by government agencies to more than 60% of all projects that they execute. 33% of respondents of consulting firms, however , indicate that LCC is used in more than 60% of all the projects that they execute.
- Government agencies have been aware of the concept for a longer time. This is indicated by the fact that about ¾ (81%) of all government agencies were aware of the concept and introduced to it more than three years ago while only 2/3 (67%) of consulting firms were introduced to it more than three years ago.
- About 80% of LCC data were dependent on three sources, namely: manufactures or suppliers, predictive calculations, and experience
- There is little consultation of records reflected in their being used by only about 1/6 of respondents in both government (14%) and consulting firms (13%).

Throughout the discussions with Islam Kabbani from the General Directory and Military Works (GDMW), he indicated that problems related to data are severely affecting the application of LCC which comes first as a result of lack of perfect standards for maintenance, operation, and replace ment.

LCC expansion in future

Table 4.36 indicates that responses to expansion of LCC in government agencies are as follows: one and six have ticked "strongly agree" and "agree" whereas four respondents have ticked " somewhat agree" respectively.

Table 4.36 Frequency and Percentage of Agreement on Expansion By Government

AGREEMENT LEVEL	FREQUENCY (# RESP.)	PERCENT (%)
A. Strongly agree	1	9
B. Agree	6	55
C. Somewhat agree	4	36
D. Don't agree	0	0
E. Don't know	0	0
	11	

Table 4.37 Frequency and Percentage of Agreement on Expansion By Firms

AGREEMENT LEVEL	FREQUENCY (# RESP.)	PERCENT (%)
A. Strongly agree	3	25
B. Agree	5	42
C. Somewhat agree	1	8
D. Don't agree	1	8
E. Don't know	2	17
	12	

Table 4.37 indicates that responses of consulting firms to agreement on expansion are as follows: three and five respondents ticked " strongly agree '' and "agree" whereas two respondents ticked "somewhat agree" and "don't agree " respectively . Only two respondents ticked "don't know ".

Size of LCC staff

Table 4.38 indicates that responses of government about size of LCC staff are as follows: one respondent (19 %) has not assigned any person, two respondents (29%) have assigned only one person, six respondents (55 %) have assigned two to five persons, one respondent (19 %) has assigned six to ten persons and one assigned more than ten persons.

Table 4.38 Frequency and Percentage of Sizes of LCC Staff in Government

STAFF SIZE	FREQUENCY (# RESP.)	PERCENT (%)
A. None	1	9
B. One	2	18
C. Two to five	6	55
D. Six to ten	1	9
E. More than ten	1	9
	11	

Table 4.39 Frequency and Percentage of Sizes of LCC Staff in Firms

STAFF SIZE	FREQUENCY (# RESP.)	PERCENT (%)
A. None	1	8
B. One	3	25
C. Two to five	3	25
D. Six to ten	4	33
E. More than ten	1	8
	12	

Table 4.39 indicates that responses of consulting firms to sizes of LCC staff are as follows: one respondent has not assigned any person , three respondents have assigned one person , three respondents have assigned two to five persons , four respondents have assigned six to ten persons , and one has assigned more than ten persons.

Reference for parties to conduct life cycle costing in government

Table 4.40 indicates that responses to reference references of parties performing LCC for government are as follows : (5 of 11) representing 45 % indicated that LCC is being conducted by their internal staff. One respondent indicated that LCC is being conducted by outside consultation, four respondents indicated that LCC is being conducted by both internal staff and outside consultation, and only one respondent indicated other references. The other references are represented by financial and engineering committees.

Table 4.40 Frequency and Percentage of Parties Conducting LCC in Government

PARTY REFERENCE	FREQUENCY (# RESP.)	PERCENT (%)
A. Internal staff from the department	5	45
B. Outside consultation	1	9
C. Both A and B	4	36
D. Others	1	9
	11	

Enforcement of LCC on Public Construction Projects

Table 4.41 indicates that responses of government agencies to the type / size of projects where LCC should be enforced during design are as follows : 33 % of respondents like LCC to be enforced in all construction projects , 25 % of respondents like LCC to be enforced only in projects over 5 millions SR (MSR) budget, 8 % of respondents like LCC to be enforced in projects over 15 MSR budget, 17 % like LCC to be enforced in projects having high operating and maintenance budgets and another 17 % like LCC to be enforced in other types of projects. The other types of projects include :

- Repetitive type projects (small or medium) that satisfy good savings by using a specific design and that could be applied to similar projects such as schools , hospitals , ...etc.
- Renovation projects that involve the decision weather to renovate or re-build.

Table 4.41 Frequency and Percentage of Where LCC Should be Enforced By Government

PROJECT TYPE	FREQUENCY (# RESP.)	PERCENT (%)
A. All construction prcjects	4	33
B. Construction projects that cost 5 MSR or more	3	25
C. Construction projects that cost 15 MSR or more	1	8
D. Construction projects that cost 50 MSR or more	0	0
E. Construction projects that have high operation and maintenance budget	2	17
F. Others.	2	17
	12	

Table 4.42 Frequency and Percentage of Where LCC Should be Enforced By Firms

PROJECT TYPE	FREQUENCY (# RESP.)	PERCENT (%)
A. All construction projects	8	67
B. Construction projects that cost 5 MSR or more	3	25
C. Construction projects that cost 15 MSR or more	0	0
D. Construction projects that cost 50 MSR or more	1	8
E. Construction projects that have high operation and maintenance budget	0	0
F. Others.	0	0
	12	

Table 4.42 indicates that responses of consulting firms to the type / size of projects where LCC should be enforced during design are as follows : 67 % of consulting firm respondents like LCC to be enforced on all construction projects, 25 % of respondents like LCC to be enforced only for 5 MSR projects or more and only 8.3 % like LCC to be enforced for 50 MSR projects or more.

Previous statistics indicate the following :

- 69% of government agencies and 56% of consulting firms "strongly agree " or "agree "on expansion of LCC.
- Government agencies and consulting firms have employed a specialized personnel to do LCC. This is indicated by the fact that about ¾ (73) of government agencies and 2/3 (67%) of consulting firms have employed more than two persons to do the LCC, although ½ of respondents who perform LCC have other work besides that.

- 1/3 (33%) of government agencies and 2/3 (67%) of consulting firms have encouraged the enforcement of LCC to all construction projects. Others have some conservation on type or size of projects where LCC should be enforced.

There are some difficulties in the expansion of LCC in government due to legal and financial limitations represented by an old purchasing system which is based on initial costs measures and not total costs (Al-Tasan , King Saud University).

4.3 Problems in application of LCC

Based on a list containing 26 problems affecting the application of LCC, that represents the third part of the questionnaire, survey responses from 11 government agencies and 12 consulting offices were received and severity indexes for each problem were calculated. Table 4.43 demonstrates the government responses while table 4.44 demonstrates offices responses.

Results of the survey

Based on a survey of the responses, a severity index was calculated to reflect the severity of each individual problem and problem groups. The severity index was calculated as follows :

$$severity - index = \left(\frac{\sum_{i=0}^{i=4} a_i x_i}{\sum_{i=0}^{i=4} x_i} \right) \qquad (4.1) \qquad \text{(Al-Hazmi , 1987)}$$

Where :

a_i = constant expressing the weight given to $i.$, x_i = variable ex pressing the frequency of responses for $i = 0, 1, 2, 3, 4$.

The average index for the problem group in application is the average of each individual problem in same group.

Spearman rho (ρ) :

The Spearman's Rank Correlation is one of the rank correlation methods and it was used to measure and compare the association between the ranking of government and consulting offices for individual and problem groups. In

Spearman's Rank Correlation, the following formula is used (Pfaffenberger and Patterson ,1977):

$$rho(\rho) = 1 - \frac{6 \cdot D^2}{N(N^2 - 1)} \qquad (4.2)$$

where D = Difference between the government ranking and consulting offices ranking for individual or group problem , N = number of rank variables.

The correlation coefficient varies between a value of +1 and -1, where +1 implies a perfect positive relationship (agreement), while -1 results from perfect negative relationship (disagreement). It might be said then that sample estimates of correlation coefficient close to unity in magnitude imply good correlation, while values near zero indicate little or no correlation (Walpole & Myers 1978).

Analysis of Data :

The severity indexes were grouped to reflect the respondents' ratings as follows :

Strongly severe	$87.5 < I \leq 100$
Severe	$62.5 < I \leq 87.5$
Somewhat severe	$37.5 < I \leq 62.5$
Somewhat not severe	$12.5 < I \leq 37.5$
Not severe	$0 < I \leq 12.5$

Table 4.43 shows the severity index for individual problems in government agencies while table 4.44 shows the severity index for individual problems in consulting offices. In the same manner , table 4.45 shows the severity index for problem groups in government while table 4.46 shows the severity index

for problem groups in consulting offices. Based on the foregoing classification, the following could be indicated:

For government agencies :

- Individual problems:

  Twenty-four individual problems rated "severe" and two individual problems rated " somewhat severe".

- Problem Groups :

  Four groups fall in the "severe" category and one group falls in the "somewhat severe" .

For consulting firms :

- Individual Problems:

  Six individual problems rated as " severe" and twenty problems rated "somewhat severe".

- Problem Groups:

  All groups fall in the " somewhat severe" category.

Other problems added by respondents are as follows:

In government agencies :

- Violation of LCC concept to government systems are based on initial cost in selecting alternatives and in bidding.

In consulting offices:

- Resistance of management to introduction of new concepts.
- Unclear concept to clients.
- Time and cost incurred to update the in-house data base management system.

Table 4.43 Results of Government Agencies' Survey of Problems

Problems Definition [1]	Strongly Severe [2]	Severe [3]	Some what severe [4]	Some what not severe [5]	Not Severe [6]	Severity Index [7]
(a) Knowledge Problems						
Unfamilianzation of design-to-cost concept	4	2	4	0	1	68
Lack of Knowledge of the concept	5	3	2	1	0	77
Unknown relation between initial and running cost	2	3	5	1	0	64
Unavailability of satisfactory references	5	2	3	0	1	73
(b) Data Problems						
Unavailability of capital cost data	3	3	3	1	1	64
Unavailability of maintenance data	4	4	1	2	0	73
Unavailability of operational data	4	3	3	1	0	73
Unavailability of interest rate data	4	3	3	1	0	73
Unavailability of time life data	3	3	5	0	0	70
Large volume of data needed	2	5	4	0	0	70
Unavailability of standard method for collecting and recording of data	3	2	4	2	0	64
Unavailability of data base management system	2	4	3	2	0	64
(c) Procedure Problems						
Unreliability of decisions taken	4	1	6	0	0	70
Lack of integrity of forecast	3	3	5	0	0	70
Majority of LCC calculations involve uncertainty	3	4	4	0	0	73
Unavailability of qualified staff	4	3	3	1	0	73
Unavailability of qualified consultant	6	2	3	0	0	82
(d) Management Problems						
Unacceptance of the concept	3	4	1	3	0	66
Government non-enforcement of LCC	4	3	3	1	0	73
Client pressure to meet the capital budget limit	4	4	3	0	0	77
Client pressure to meet time deadline on design	5	3	2	1	0	77
Unclear benefits of LCC to Client	2	6	3	0	0	73
Improper planning and control of manag. tasks at different LCC stages	2	6	3	0	0	73
(e) Cost Problems						
Cost to be paid to designer to conduct LCC	1	4	5	1	0	61
Cost to be paid for collecting and analyzing of data	1	4	6	0	0	64
Difficulties in identifying cost components	1	3	6	1	0	59

Table 4.44 Results of Consulting Offices' Survey of Problems

Problems Definition [1]	Strongly Severe [2]	Severe [3]	some what severe [4]	Some what not severe [5]	Not Severe [6]	Severity Index [7]
(a) Knowledge Problems						
Unfamiliarization of design-to-cost concept	3	2	4	1	2	56
Lack of Knowledge of the concept	0	5	4	2	1	52
Unknown relation between initial and running cost	0	4	3	1	4	40
Unavailability of satisfactory references	1	2	7	0	2	50
(b) Data Problems						
Unavailability of capital cost data	2	1	5	0	3	48
Unavailability of maintenance data	2	4	4	1	1	60
Unavailability of operation data	2	5	3	1	1	63
Unavailability of interest rate data	2	5	4	1	0	67
Unavailability of time life data	3	4	3	1	1	65
Large volume of data needed	0	5	5	0	2	52
Unavailability of standard method for collecting and recording of data	2	5	3	0	2	60
Unavailability of data base management system	4	3	3	1	1	67
(c) Procedure Problems						
Unreliability of decisions taken	2	2	3	4	1	50
Lack of integrity of forecasting	3	0	6	2	1	54
Majority of LCC calculations involve uncertainty	2	3	4	2	1	56
Unavailability of qualified staff	3	2	5	1	1	60
Unavailability of qualified consultant	2	4	4	1	1	60
(d) Management Problems						
Unacceptance of the concept	2	4	2	2	2	54
Government non-enforcement of LCC	3	2	5	0	2	58
Client pressure to meet the capital budget limit	2	3	3	2	2	52
Client pressure to meet time deadline on design	3	3	4	1	1	63
Unclear benefits of LCC to Client	3	4	3	1	1	65
Improper planning and control of manag. tasks at LCC stages	1	2	7	1	1	52
(e) Cost Problems						
Cost to be paid to designer to conduct LCC	3	3	2	3	1	58
Cost to be paid for collecting and analyzing of data	3	2	4	2	1	58
Cost Problems						
Difficulties in identifying cost components	1	2	6	1	2	48

Table 4.45 Severity Index of Problem Groups in Government

Group	Group Description	Average Sev. Index
A	Knowledge Problems	70
B	Data Problems	69
C	Procedure Problems	74
D	Management Problems	73
E	Cost Problems	61

Table 4.46 Severity Index of Problem Groups in Firms

Group	Group Description	Average Sev. Index
A	Knowledge Problems	49
B	Data Problems	60
C	Procedure Problems	56
D	Management Problems	57
E	Cost Problems	55

Fig. 4.2 Results of Government Agencies' Evaluation

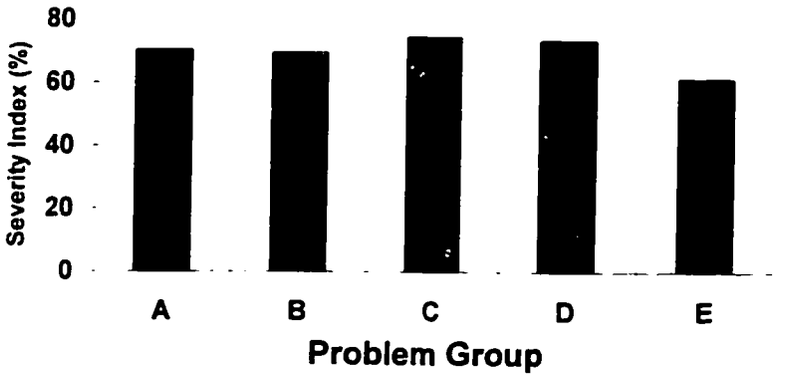
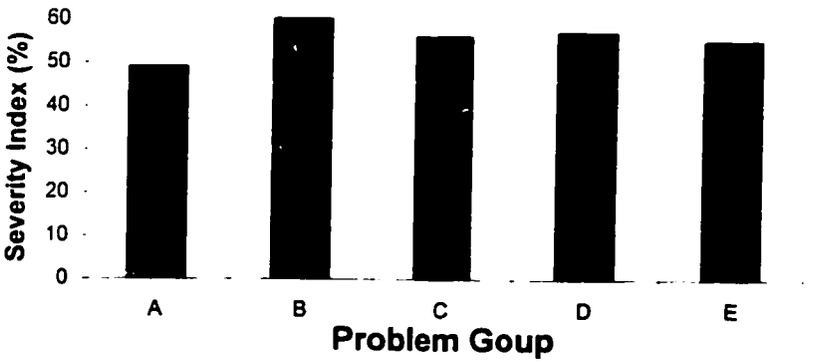


Fig. 4.3 Results of Consulting Offices' Evaluation



Problems Ranking

Table 4.47 and table 4.48 indicate the ranking of individual problems by government agencies and consulting firms while table 4.49 and table 4.50 indicate ranking of problem groups. The statistics indicate the following:

For government agencies :

- Individual Problems:

  Unavailability of qualified consultants , management pressure to meet budget and design limits are the most severe hurdles in the application of LCC, with severity indexes of 82% , 77% and 77% respectively.

- Problem Groups : Procedure problems , management problems and knowledge problems are the most severe hurdles in the application of life cycle costing with severity indexes of 74% , 73% and 70% respectively.

For consulting offices

- Individual Problems: Unavailability of data base management systems and unavailability of interest rate and life time data are the most severe hurdles in the application of LCC with severity indexes of 67% , 67% and 65% respectively.

- Problem Groups: Data problems, management problems, and procedure problems are the most severe hurdles in the application of LCC with severity indexes of 60% , 57% and 56% respectively.

Table 4.47 Ranking of Problems in Government

Rank	Problems Definition	Severity index
1	Unavailability of qualified consultant	82
2	Management pressure to meet the capital budget limit	77
3	Management pressure to meet time deadline on design	77
4	Lack of knowledge of the concept	77
5	Government non-enforcement of LCC	73
6	Improper planning and control of manag. tasks at LCC stages	73
7	Majority of LCC calculations include uncertainty	73
8	Unavailability of enough references	73
9	Unavailability of interest rate data	73
10	Unavailability of maintenance data	73
11	Unavailability of operation data	73
12	Unavailability of qualified staff	73
13	Unclear services of LCC to Management.	73
14	Lack of integrity of forecasting	70
15	Large volume of data needed	70
16	Unavailability of life time data	70
17	Unreliability of decision taken	70
18	Unfamiliarization of design-to-cost concept	68
19	Unacceptance of the concept	66
20	Cost to be paid for collecting and analyzing of data	64
21	Unavailability of capital cost data	64
22	Unavailability of data base management system	64
23	Unavailability of standard method for collecting of data	64
24	Unknown relation between initial and running cost	64
25	Cost to be paid to designer to conduct LCC	61
26	Difficulties in identifying cost components	59

Table 4.48 Ranking of Problems in Firms

Rank	Problems Definition	Severity index
1	Unavailability of data base management system	67
2	Unavailability of interest rate data	67
3	Unavailability of life timedata	65
4	Unclear services of LCC to Client	65
5	Client pressure to meet time deadline on design	63
6	Unavailability of operation data	63
7	Unavailability of maintenance data	60
8	Unavailability of qualified consultant	60
9	Unavailability of qualified staff	60
10	Unavailability of standard method for collecting of data	60
11	Cost to be paid to designer to conduct LCC	58
12	Cost to be paid for collecting and analyzing of data	58
13	Government non-enforcement of LCC	58
14	Majority of LCC calculations involve uncertainty	56
15	Unfamiliarization of design-to-cost concept	56
16	Lack of integrity of forecasting	54
17	Unacceptance of the concept	54
18	Client pressure to meet the capital budget limit	52
19	Improper planning and control of manag. tasks at LCC stages	52
20	Lack of knowledge of the concept	52
21	Large volume of data needed	52
22	Unavailability of enough references	50
23	Unreliability o f decision taken	50
24	Difficulties in identifying cost components	48
25	Unavailability of capital cost data	48
26	Unknown relation between initial and running cost	40

Table 4.49 Ranking of Problem Groups by Government

RANK	Group	Group Description	Average Sev. Index
1	C	Procedure Problems	74
2	D	Management Problems	73
3	A	Knowledge Problems	70
4	B	Data Problems	69
5	E	Cost Problems	61

Table 4.50 Rank of Problem Groups by Consulting Firms

RANK	Group	Group Description	Average Sev. Index
1	B	Data Problems	60
2	D	Management Problems	57
3	C	Procedure Problems	56
4	E	Cost Problems	55
5	A	Knowledge Problems	49

Agreement between both parties

For individual problems: Table 4.51 shows that the degree of agreement on ranking (*rho*) between government agencies' and consulting firms' - using equation 4.2 - is only 0.22

For group problems : Table 4.52 shows that the degree of agreement on ranking (*rho*) between government agencies' and consulting firms' - using equation 4.2 - is only 0.11

The rank correlation between the parties shows that there is little agreement between the government agencies and consulting offices. However the agreement between both parties on individual problems (.22) is relatively higher than problem groups (0.11). This is due to the difference in responsibility and interest of each party.

In the following section, the researcher wants to test the hypothesis that "government agencies and consulting offices generally do not agree on the severity ranking of individual and group problems". The 't' test is suitable and used in this study.

Test of hypothesis :

This section tests the agreement between the parties . The null hypothesis (section a) below is tested by comparing the calculated value of t with the critical test value in the result given in part C below :

a) The null hypothesis Ho : r = o

The null hypothesis says that the parties do not agree on the severity rank of problems and they differ in their responses with a correlation of zero among them.

ii) The calculated value of t

$$t = \left[\frac{(n-2)\cdot r^2}{(1-r^2)}\right]^{\frac{1}{2}} \qquad (4.3)\ (\text{KENDALL,1960})$$

Where :

r = the Spearman correlation founded on table 4.45 and table 4.46

n = the number of observations.

For individual problems :

By substituting the r values present in Table 4.49, the t values is found to be 1.10

For problems groups :

By substituting the r values present in Table 4.52, the t value is found to be .174

C. The critical test value :

$$t_{0.05},\infty- = 1.645$$

D. Decision :

In this case, the calculated values are smaller than the critical value (1.645). Therefore, the null hypothesis is accepted and it is concluded that both parties don't agree on the severity rank of group or individual problems. This disagreement is valid because each party sees the application of life cycle cost from a different angle, based on responsibility and interest.

In conclusion, although the test of hypothesis states that both parties disagree on ranking of problems, a careful analysis of tables 4.47 and 4.48, indicates that the following conclusions are made by both parties :

- The chief cause for not applying LCC in government agencies or public sectors is client or management pressure to meet the deadline of design.

- The lack of human resources (qualified consultants and staff) and material (data and data quality) are considered the main reasons for not applying LCC more extensively.
- The unknown of relation and trade-off between capital cost and running cost are less effective on the application.

Table 4.51 Degree of Agreement on Rank of Individual Problems

Problems Definition [1]	Government Rank [2]	Consultants Rank [3]	D^2 [4]
Un- familiarization of design-to-cost concept	18	15	9
Lack of knowledge of the concept	4	16	144
Unknown relation between initial and running cost	24	26	4
Unavailability of satisfactory references	8	22	196
Unavailability of capital cost data	21	25	16
Unavailability of maintenance data	10	7	9
Unavailability of operation data	11	6	25
Unavailability of interest rate data	9	2	49
Unavailability of life time data	16	3	169
Large volume of data needed	15	21	36
Unavailability of standard method for collecting and recording of data	23	10	169
Unavailability of data base management system	22	1	441
Unreliability of decision taken	16	23	49
Lack of integrity of forecasting	14	16	4
Majority of LCC calculations involve uncertainty	7	14	49
Unavailability of qualified staff	12	9	9
Unavailability of qualified consultant	1	8	49
Unacceptance of the concept	19	17	4
Government non-enforcement of LCC	5	13	64
Client pressure to meet the capital budget limit	2	18	256
Client pressure to meet time deadline on design	3	5	4
Unclear benefits of LCC to Client	13	4	81
Improper planning and control of manag. tasks at LCC stages	6	19	169
Cost to be paid to designer to conduct LCC	25	11	196
Cost to be paid for collecting and analyzing of data Cost Problems	20	12	64
Difficulties in identifying cost components	26	24	4

Spearman(rho) = 1-6 (2269) /26 /(26^2-1) = 0.22

Table 4.52 Degree of Agreement of Rank of Group Problems

Major Application Problem	Gov. rankin	Con. rankin	D^2
Knowledge related problems	3	5	4
Data related problems	4	1	9
Procedures related problems	1	3	4
Management related problems	2	2	0
Cost related problems	5	4	1
Note : Spearman(rho) = 1 - 6(18)/5/24 = .1 , total = 18			

Comments added by respondents are as follows:

- In the application of the concept, there are two types of problems ; first, problems related to the client, which include lack of understanding of the concept and lack of appreciation of LCC by the client, which is preferably from the private sector since here there is greater concern for economic matters, and, second, application problems, which include lack of data and maintenance data especially.
- Clients, consultants, and other parties should be introduced to LCC so that they will under stand and appreciate the concept.
- In application of the concept , there are many clients, no matter how rich, who expect consultants to render consultation services free of charge. This is due to a lack of understanding of the concept and ignorance of the importance of the roles that LCC plays.

Chapter 5

Summary, Conclusion and Recommendations

Summary :

In the early period of the construction boom, the building materials utilized were unsuited to the harsh climatic conditions of the Kingdom. Therefore the building and infrastructure constructions of this period were subject to premature aging and increased maintenance and replacement costs.

One of the major goals for the sixth plan (1995 - 2000) is to control the costs of maintenance services and to increase the operating life of facilities while lowering future costs (Sixth plan , 1995).

Thus there was a need to measure the usage extent of techniques such as Life Cycle Costing (LCC), and the corrective measures that were taken, as that would accurately reflect the implementation of this aim. It would also be necessary to find the obstacles (if any), to its application and find ways to overcome them. LCC is a unique technique that considers total ownership costs over the useful life of the facility, not only the initial building costs that have been the traditional method.

In this study, the LCC concept, its history and current local practice, the significance of this study, its objective and application methodology are discussed. The LCC process has been demonstrated by presenting the estimating

process and its components, basic economic principles, and problems that affect the application with their explanation.

A questionnaire was developed to determine the extent of application of LCC and explore problems affecting the application. The questionnaire was distributed to all Government agencies that have the authority to supervise the execution of public construction projects and to consulting offices that pr vide technical services to Government agencies. The questionnaire is divided into three parts: 1) The Respondents organization's description, 2) LCC application practice, and 3) Problems affecting the application. The part concerning problems in application was developed to also measure the severity of known problems and to discover any additional problems. The ranking ranges from "strongly severe " to "not severe".

The results of this study are based on sixty-eight (68) verified responses to the questionnaire that was mailed to forty-five Government agencies and two hundred and fifty consulting firms.

Lastly a hypothesis that the parties generally agree on the ranking of the severity problems was tested by the Rank Correlation Coefficient Method.

CONCLUSIONS:

1. Consulting firms have a better in depth knowledge of LCC compared to Government agencies. This is indicated by the fact that about 1/3 (37%) of government agencies know the concept "well" or better while 1/2 the responding consulting firms know the concept "well" or better. This is due to the consulting firms' experience and/or due to knowledgeable and

trained expatriate staff, who had acquired their experience from their home countries. However about ¼ of the responding consulting firms indicated that they only know the concept "little" or "none", compared with 13% for Government agencies.

2 Although the concept of LCC is known to most engineers, the frequency of application of LCC by Government agencies and consulting firms is low, due to some difficulties in its application.

3 The study indicates that the Present Worth Method (PW) And Equivalent Annual Cost Method (EUAC) are being used for economic estimation purposes (other than LCC) by about ½ of respondents in Government agencies and consulting firms.

4. LCC is being applied by about ⅔ (67%) of Government agencies and ¾ of the responding consulting firms.

5 About 2/3 of Government agency respondents and 1/3 of consulting firms respondents, who apply LCC, claimed that they have used the formal procedures.

6. The extent of application of LCC is shown by the fact that Government agencies do not use it for more than 60% of all projects that they execute. 33% of responding consulting firms, however, indicate that LCC is used in more than 60% of all the projects that they execute.

7 Government agencies have been aware of the concept for a longer time. This is indicated by the fact that 81% of all government agencies were aware of the concept and introduced to it more that three years ago while only 67% of consulting firms were introduced to it more than three years ago.

8. LCC data was extensively (more than 80%) obtained from three sources, namely: manufacturers or suppliers, predictive calculations and experience.
9. Records were not considered as a source of reliable data that is reflected in the fact that records are used by about 1/6 of respondents in both Government agencies (14%) and consulting firms (13%).
10. 69% of Government agencies and 56% of consulting firms "strongly agree" or "agree" that LCC should be more widely applied.
11. Government agencies and consulting firms have considered the employment of specialized dedicated personnel to do formal LCC. This is indicated by the fact that about ¾ (73) of Government agencies and 2/3 (67%) of consulting firms have employed more than two persons to do the LCC. However, ½ of respondents who perform LCC have other duties beside LCC.
12. 1/3 (33%) of Government agencies and 2/3 (67%) of consulting firms have encouraged the enforcement of LCC for all construction projects. Others have some reservations, limiting LCC to the type or size of projects where LCC should be enforced.
13. Government agencies and consulting firms, due to the difference of responsibility and work interest, generally differ in their ranking of the problems that affect LCC application. However, it could be concluded that both parties have agreed on the following:
    a) The chief cause for not applying LCC in government agencies or the public sectors is client or management pressure to meet the deadline for design approval.

b) The lack of human resources (qualified consultants and staff) and material resources (sufficient data and data quality) are considered the main reason for not applying LCC more extensively.

c) Both Government agencies and consulting firms agreed that the unknown relation between capital cost and running cost had the least impact on the implementation of LCC.

RECOMMENDATIONS :

1- In designing any project, future costs should be considered rather than the initial cost only.

2- The concept of LCC could be made easier in application by providing the appropriate data, forms and programs designed for LCC analysis.

3- It would appear that data relating to LCC will not become available unless it is mandated by a Government agency, such as the Department of Statistics, who will ensure its quality and make it easily accessible to the Public though periodic publications

4- The logic of LCC could be acceptable in evaluating of simple decisions; however when the evaluation includes the manipulation of bulky information related to construction material, formal procedures of LCC should be adopted.

5 -The application of LCC should be mandatory for all Government agencies. On the other hand, for private projects, LCC reports that reflect the reduction on total subsidiary costs for electricity, water and others should be submitted to the concerned department for review and recommendations.

6- The public and private sector should not accept any design unless they are sat isfied with the LCC analysis.

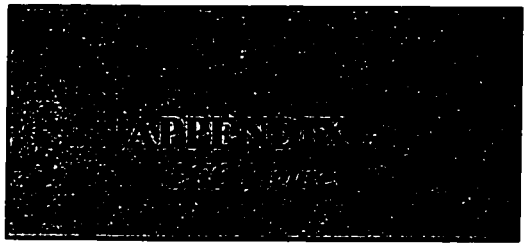
7- Government standards should be modified to suit the new technology related to material and should not stick to the old standards.

Recommendations for Further Study :

1. Researchers have to search and identify options that would bring about the greatest potential in savings. This could be done by repetitive appli - cation of LCC to variations of designs. The study could include :

- The effect of building form on configuration of LCC costs.
- The sensitivity of LCC to the principal design options such as total area, cladding type, roof type, number of stories, etc.

2. To identify and set standards for maintenance tasks which would satisfy the policies of government or clients.
3. Explore the capability of the existing consulting offices to handle the LCC studies interms of technical capability like availability of com puter systems, staff experience, staff expertise, etc.
4. Design an expert system that could select the proper materials assuming that life period, efficiency, maintenance costs, operating costs and other LCC considerations will be given.



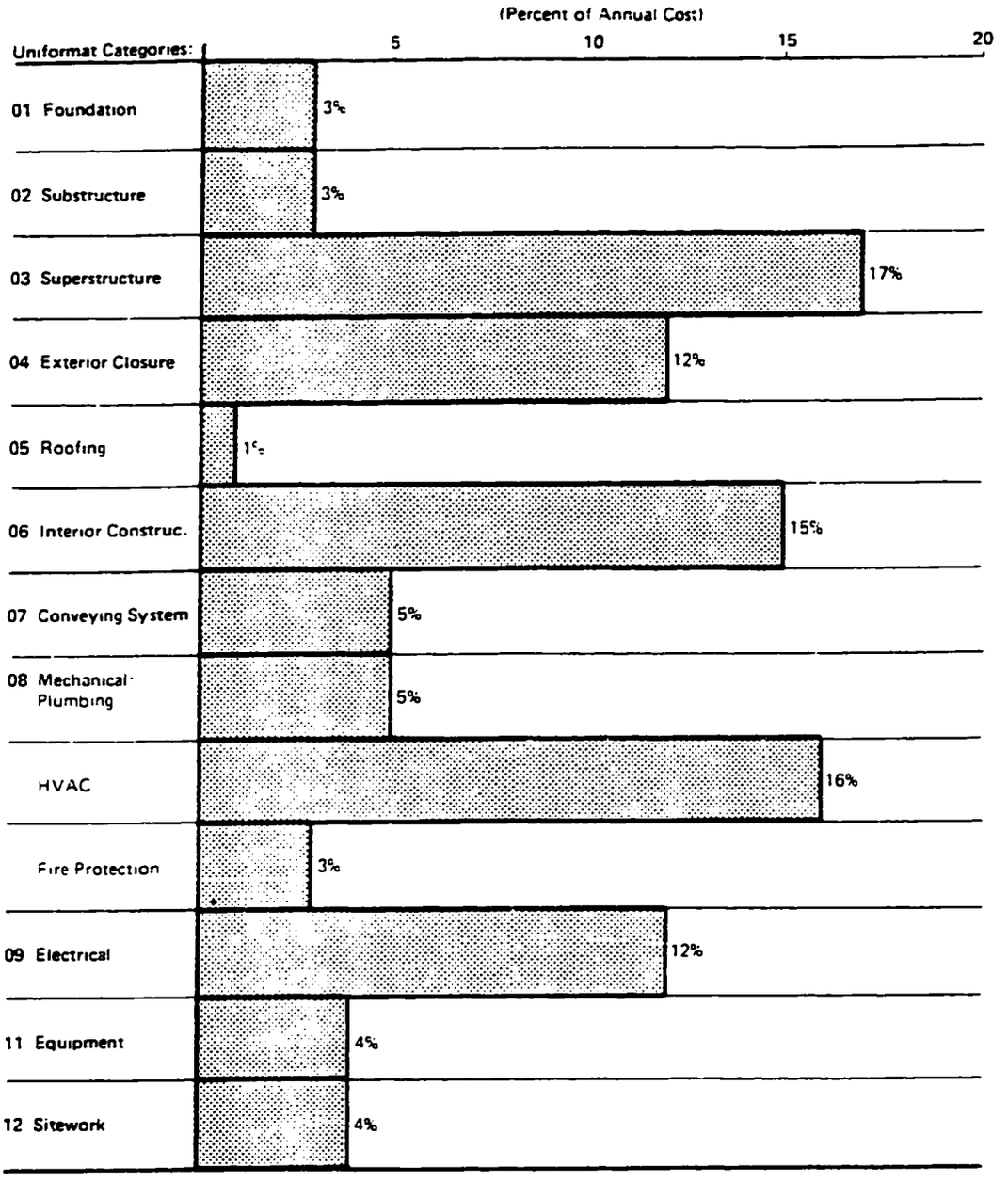


Figure A-1 : Relative cost impact of initial costs for a typical office building (Dell'Isola , 1995).

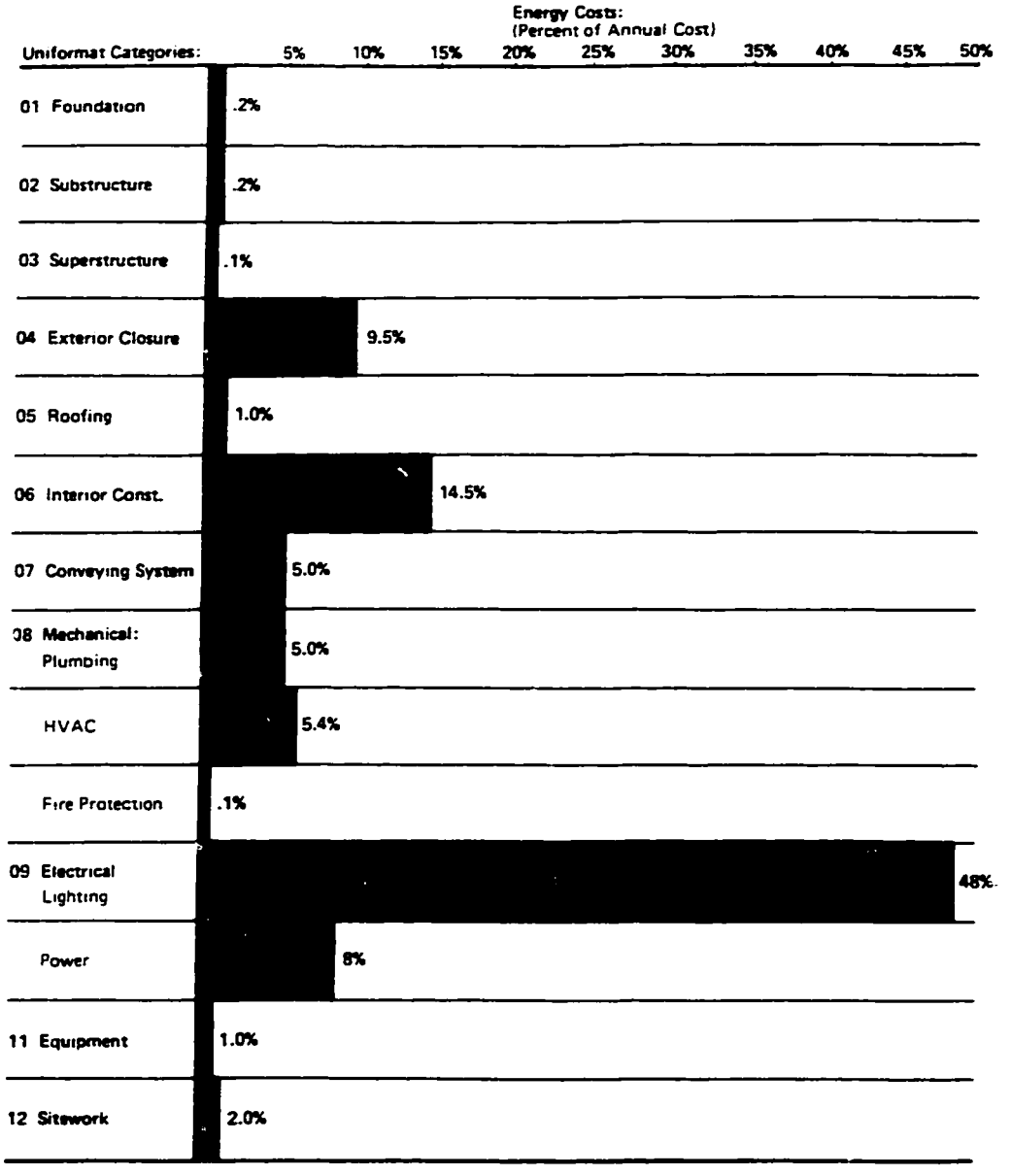


Figure A - 2: Relative cost impact of energy (Dell'Isola , 1995).

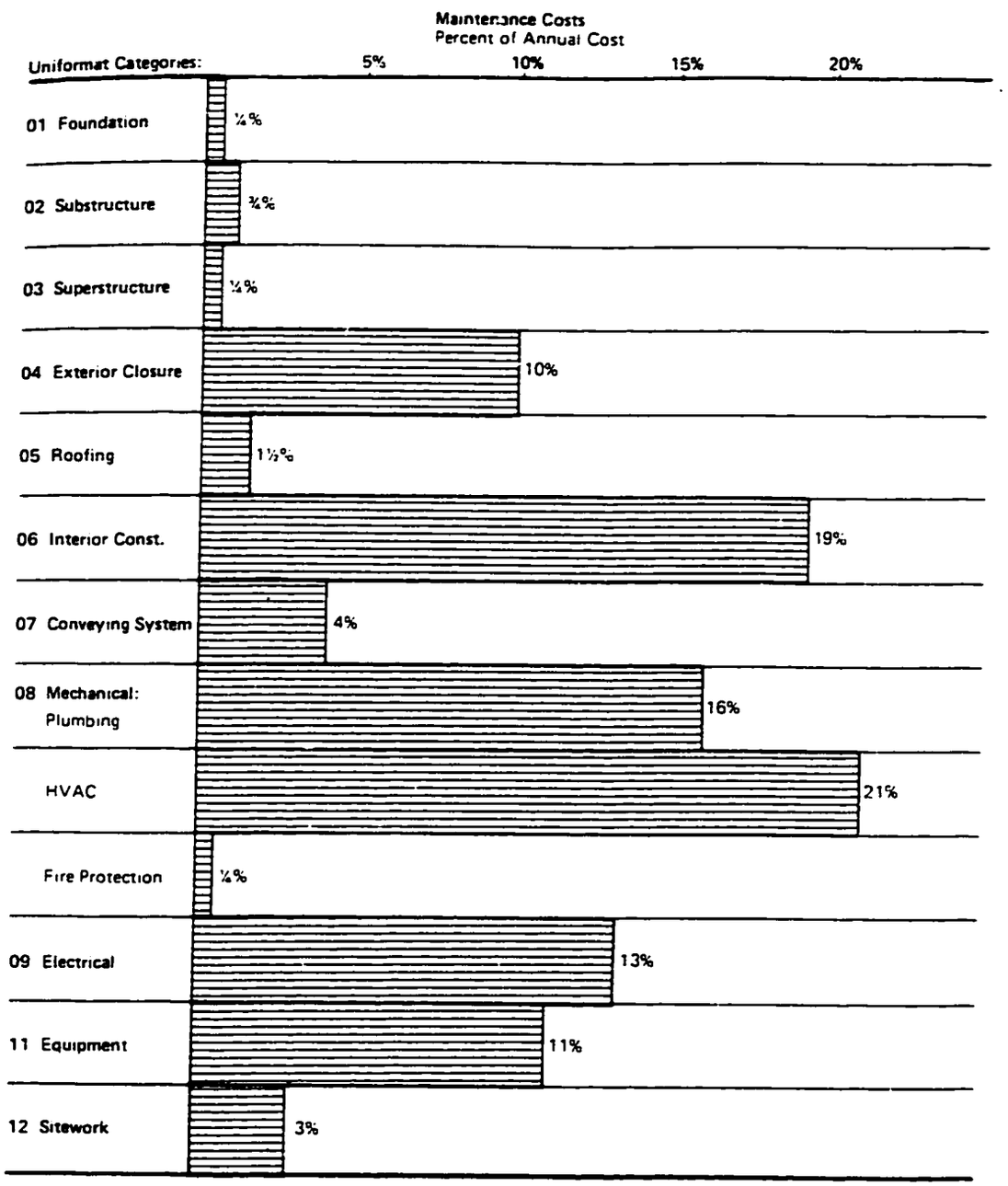


Figure A - 3 : Relative cost impact of maintenance (Dell'Isola , 1995).

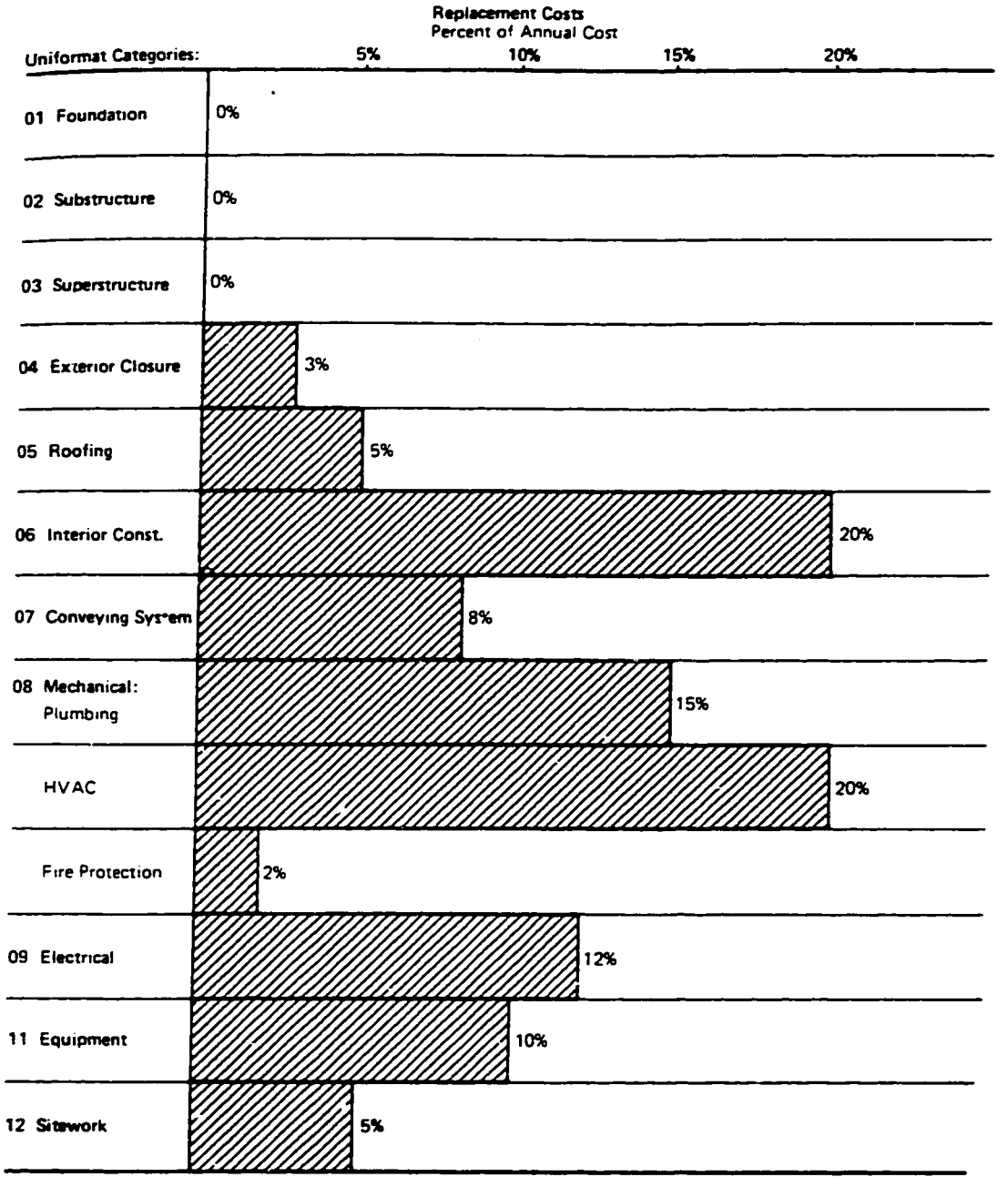
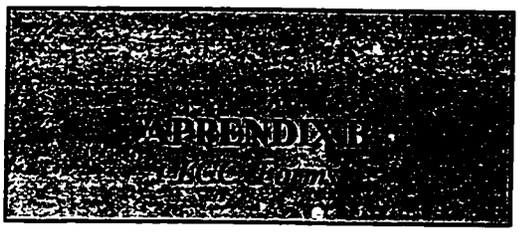


Figure A - 4 : Relative cost impact of replacement (Dell'Isola , 1995).



LIFE CYCLE COST ANALYSIS (Present Worth Method)
CONFIDENCE INDEX (CI) COMPUTATION
Project/Location:

Subject:
Description:

Project Life Cycle = YEARS Discount Rate = % COST ITEMS:	ESTIMATES RANGE			DIFFERENCES IN ESTIMATES				PRESENT WORTH		
	LOW	HIGH	BEST	LOW SIDE	HIGH SIDE	DELTA %	ok	BEST ESTIMATE	DELTA	DELTA^2
ALTERNATIVE L(ow)										
Totals										
ALTERNATIVE H(igh)										
Totals										

Note = If high and low 90% estimates > 25%, then use sensitivity analysis

Difference

Sum

(Sum)^1/2

$$\text{Confidence Index} = \frac{PW(High) - PW(Low)}{(PW\ Diff(High)^2 + PW\ Diff(Low)^2)^{1/2}} = \frac{\dots\dots}{} = \qquad =$$

Confidence Assignment:
Low: CI < 0.15
Medium: 0.15 < CI < 0.25
High: CI > 0.25

FIG. B-1 : Confidence Index Computation Form (Dell'Isola,1995)

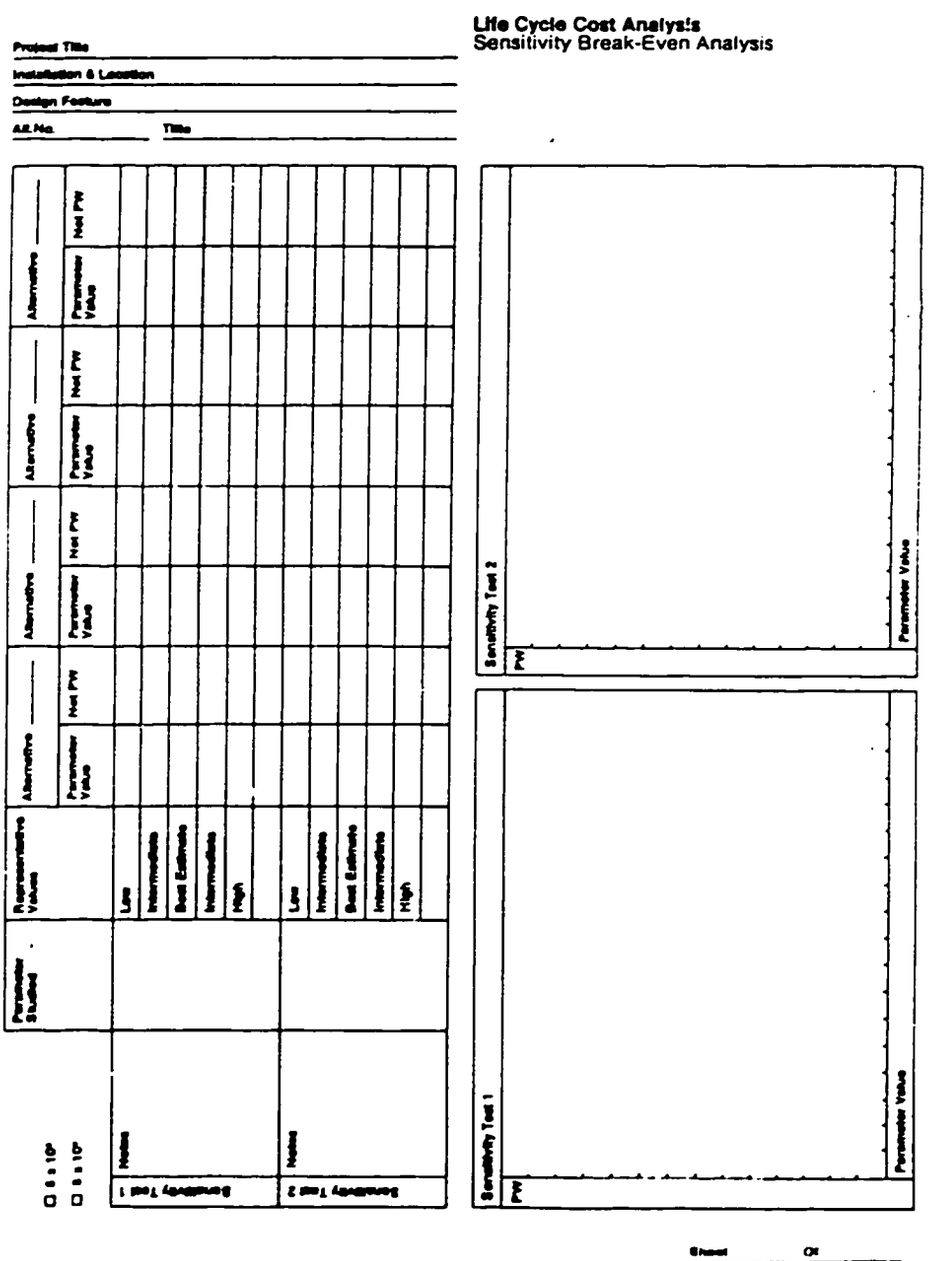


FIG. B-2 : Sensitivity Break-even Analysis Form (Dell'Isola,1995)


APPENDIX C
Interviews for ILCC

Interest table for life cycle costing—6% discount rate.

Factor:	SCA Single Compound Amount	PW Single Present Worth	USF Uniform Sinking Fund	PP Periodic Payment	UCA Uniform Compound Amount	PWA Present Worth Annuity	
Given:	P	F	F	P	A	A	
Find:	F	P	A	A	F	P	
n							n
1	1.0700	0.9346	1.00000	1.07000	1.000	0.935	1
2	1.1449	0.8734	0.48309	0.55309	2.070	1.808	2
3	1.2250	0.8163	0.31105	0.38105	3.215	2.624	3
4	1.3108	0.7629	0.22523	0.29523	4.440	3.387	4
5	1.4026	0.7130	0.17389	0.24389	5.751	4.100	5
6	1.5007	0.6663	0.13980	0.20980	7.153	4.767	6
7	1.6058	0.6227	0.11555	0.18555	8.654	5.389	7
8	1.7182	0.5820	0.09747	0.16747	10.260	5.971	8
9	1.8385	0.5439	0.08349	0.15349	11.978	6.515	9
10	1.9672	0.5083	0.07238	0.14238	13.816	7.024	10
11	2.1049	0.4751	0.06336	0.13336	15.784	7.499	11
12	2.2522	0.4440	0.05590	0.12590	17.888	7.943	12
13	2.4098	0.4150	0.04965	0.11965	20.141	8.358	13
14	2.5785	0.3878	0.04434	0.11434	22.550	8.745	14
15	2.7590	0.3624	0.03979	0.10979	25.129	9.108	15
16	2.9522	0.3387	0.03586	0.10586	27.888	9.447	16
17	3.1588	0.3166	0.03243	0.10243	30.840	9.763	17
18	3.3799	0.2959	0.02941	0.09941	33.999	10.059	18
19	3.6165	0.2765	0.02675	0.09675	37.379	10.336	19
20	3.8697	0.2584	0.02439	0.09439	40.995	10.594	20
21	4.1406	0.2415	0.02229	0.09229	44.865	10.836	21
22	4.4304	0.2257	0.02041	0.09041	49.006	11.061	22
23	4.7405	0.2109	0.01871	0.08871	53.436	11.272	23
24	5.0724	0.1971	0.01719	0.08719	58.177	11.469	24
25	5.4274	0.1842	0.01581	0.08581	63.249	11.654	25
26	5.8074	0.1722	0.01456	0.08456	68.676	11.826	26
27	6.2139	0.1609	0.01343	0.08343	74.484	11.987	27
28	6.6488	0.1504	0.01239	0.08239	80.698	12.137	28
29	7.1143	0.1406	0.01145	0.08145	87.347	12.278	29
30	7.6123	0.1314	0.01059	0.08059	94.461	12.409	30
31	8.1451	0.1228	0.00980	0.07980	102.073	12.532	31
32	8.7153	0.1147	0.00907	0.07907	110.218	12.647	32
33	9.3253	0.1072	0.00841	0.07841	118.933	12.754	33
34	9.9781	0.1002	0.00780	0.07780	128.259	12.854	34
35	10.6766	0.0937	0.00723	0.07723	138.237	12.948	35
36	11.4239	0.0875	0.00672	0.07672	148.913	13.035	36
37	12.2236	0.0818	0.00624	0.07624	160.337	13.117	37
38	13.0793	0.0765	0.00580	0.07580	172.561	13.193	38
39	13.9948	0.0715	0.00539	0.07539	185.640	13.265	39
40	14.9745	0.0668	0.00501	0.07501	199.635	13.332	40

Interest table for life cycle costing—7% discount rate.

Factor:	SCA Single Compound Amount	PW Single Present Worth	USF Uniform Sinking Fund	PP Periodic Payment	UCA Uniform Compound Amount	PWA Present Worth Annuity	
Given:	P	F	F	P	A	A	
Find:	F	P	A	A	F	P	
n							n
1	1.0700	0.9346	1.00000	1.07000	1.000	0.935	1
2	1.1449	0.8734	0.48309	0.55309	2.070	1.808	2
3	1.2250	0.8163	0.31105	0.38105	3.215	2.624	3
4	1.3108	0.7629	0.22523	0.29523	4.440	3.387	4
5	1.4026	0.7130	0.17389	0.24389	5.751	4.100	5
6	1.5007	0.6663	0.13980	0.20980	7.153	4.767	6
7	1.6058	0.6227	0.11555	0.18555	8.654	5.389	7
8	1.7182	0.5820	0.09747	0.16747	10.260	5.971	8
9	1.8385	0.5439	0.08349	0.15349	11.978	6.515	9
10	1.9672	0.5083	0.07238	0.14238	13.816	7.024	10
11	2.1049	0.4751	0.06336	0.13336	15.784	7.499	11
12	2.2522	0.4440	0.05590	0.12590	17.888	7.943	12
13	2.4098	0.4150	0.04965	0.11965	20.141	8.358	13
14	2.5785	0.3878	0.04434	0.11434	22.550	8.745	14
15	2.7590	0.3624	0.03979	0.10979	25.129	9.108	15
16	2.9522	0.3387	0.03586	0.10586	27.888	9.447	16
17	3.1588	0.3166	0.03243	0.10243	30.840	9.763	17
18	3.3799	0.2959	0.02941	0.09941	33.999	10.059	18
19	3.6165	0.2765	0.02675	0.09675	37.379	10.336	19
20	3.8697	0.2584	0.02439	0.09439	40.995	10.594	20
21	4.1406	0.2415	0.02229	0.09229	44.865	10.836	21
22	4.4304	0.2257	0.02041	0.09041	49.006	11.061	22
23	4.7405	0.2109	0.01871	0.08871	53.436	11.272	23
24	5.0724	0.1971	0.01719	0.08719	58.177	11.469	24
25	5.4274	0.1842	0.01581	0.08581	63.249	11.654	25
26	5.8074	0.1722	0.01456	0.08456	68.676	11.826	26
27	6.2139	0.1609	0.01343	0.08343	74.484	11.987	27
28	6.6488	0.1504	0.01239	0.08239	80.698	12.137	28
29	7.1143	0.1406	0.01145	0.08145	87.347	12.278	29
30	7.6123	0.1314	0.01059	0.08059	94.461	12.409	30
31	8.1451	0.1228	0.00980	0.07980	102.073	12.532	31
32	8.7153	0.1147	0.00907	0.07907	110.218	12.647	32
33	9.3253	0.1072	0.00841	0.07841	118.933	12.754	33
34	9.9781	0.1002	0.00780	0.07780	128.259	12.854	34
35	10.6766	0.0937	0.00723	0.07723	138.237	12.948	35
36	11.4239	0.0875	0.00672	0.07672	148.913	13.035	36
37	12.2236	0.0818	0.00624	0.07624	160.337	13.117	37
38	13.0793	0.0765	0.00580	0.07580	172.561	13.193	38
39	13.9948	0.0715	0.00539	0.07539	185.640	13.265	39
40	14.9745	0.0668	0.00501	0.07501	199.635	13.332	40

Interest table for life cycle costing—8% discount rate.

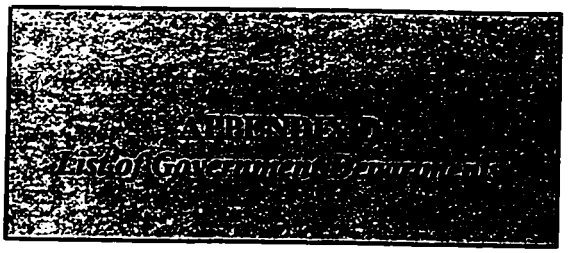
Factor:	SCA Single Compound Amount	PW Single Present Worth	USF Uniform Sinking Fund	PP Periodic Payment	UCA Uniform Compound Amount	PWA Present Worth Annuity	
Given:	P	F	F	P	A	A	
Find:	F	P	A	A	F	P	
n							n
1	1.0800	0.9259	1.00000	1.08000	1.000	0.926	1
2	1.1664	0.8573	0.48077	0.56077	2.080	1.783	2
3	1.2597	0.7938	0.30803	0.38803	3.246	2.577	3
4	1.3605	0.7350	0.22192	0.30192	4.506	3.312	4
5	1.4693	0.6806	0.17046	0.25046	5.867	3.993	5
6	1.5869	0.6302	0.13632	0.21632	7.336	4.623	6
7	1.7138	0.5835	0.11207	0.19207	8.923	5.206	7
8	1.8509	0.5403	0.09401	0.17401	10.637	5.747	8
9	1.9990	0.5002	0.08008	0.16008	12.488	6.247	9
10	2.1589	0.4632	0.06903	0.14903	14.487	6.710	10
11	2.3316	0.4289	0.06008	0.14008	16.645	7.139	11
12	2.5182	0.3971	0.05270	0.13270	18.977	7.536	12
13	2.7196	0.3677	0.04652	0.12652	21.495	7.904	13
14	2.9372	0.3405	0.04130	0.12130	24.215	8.244	14
15	3.1722	0.3152	0.03683	0.11683	27.152	8.559	15
16	3.4259	0.2919	0.03298	0.11298	30.324	8.851	16
17	3.7000	0.2703	0.02963	0.10963	33.750	9.122	17
18	3.9960	0.2502	0.02670	0.10670	37.450	9.372	18
19	4.3157	0.2317	0.02413	0.10413	41.446	9.604	19
20	4.6610	0.2145	0.02185	0.10185	45.762	9.818	20
21	5.0338	0.1987	0.01983	0.09983	50.423	10.017	21
22	5.4365	0.1839	0.01803	0.09803	55.457	10.201	22
23	5.8715	0.1703	0.01642	0.09642	60.893	10.371	23
24	6.3412	0.1577	0.01498	0.09498	66.765	10.529	24
25	6.8485	0.1460	0.01368	0.09368	73.106	10.675	25
26	7.3964	0.1352	0.01251	0.09251	79.954	10.810	26
27	7.9881	0.1252	0.01145	0.09145	87.351	10.935	27
28	8.6271	0.1159	0.01049	0.09049	95.339	11.051	28
29	9.3173	0.1073	0.00962	0.08962	103.966	11.158	29
30	10.0627	0.0994	0.00883	0.08883	113.283	11.258	30
31	10.8677	0.0920	0.00811	0.08811	123.346	11.350	31
32	11.7371	0.0852	0.00745	0.08745	134.214	11.435	32
33	12.6760	0.0789	0.00685	0.08685	145.951	11.514	33
34	13.6901	0.0730	0.00630	0.08630	158.627	11.587	34
35	14.7853	0.0676	0.00580	0.08580	172.317	11.655	35
36	15.9682	0.0626	0.00534	0.08534	187.102	11.717	36
37	17.2456	0.0580	0.00492	0.08492	203.070	11.775	37
38	18.6253	0.0537	0.00454	0.08454	220.316	11.829	38
39	20.1153	0.0497	0.00419	0.08419	238.941	11.879	39
40	21.7245	0.0460	0.00386	0.08386	259.057	11.925	40

Interest table for life cycle costing—10% discount rate.

Factor:	SCA Single Compound Amount	PW Single Present Worth	USF Uniform Sinking Fund	PP Periodic Payment	UCA Uniform Compound Amount	PWA Present Worth Annuity	
Given:	P	F	F	P	A	A	
Find:	F	P	A	A	F	P	
n							n
1	1.1000	0.9091	1.00000	1.10000	1.000	0.909	1
2	1.2100	0.8264	0.47619	0.57619	2.100	1.736	2
3	1.3310	0.7513	0.30211	0.40211	3.310	2.487	3
4	1.4641	0.6830	0.21547	0.31547	4.641	3.170	4
5	1.6105	0.6209	0.16380	0.26380	6.105	3.791	5
6	1.7716	0.5645	0.12961	0.22961	7.716	4.355	6
7	1.9487	0.5132	0.10541	0.20541	9.487	4.868	7
8	2.1436	0.4665	0.08744	0.18744	11.436	5.335	8
9	2.3579	0.4241	0.07364	0.17364	13.579	5.759	9
10	2.5937	0.3855	0.06275	0.16275	15.937	6.145	10
11	2.8531	0.3505	0.05396	0.15396	18.531	6.495	11
12	3.1384	0.3186	0.04676	0.14676	21.384	6.814	12
13	3.4523	0.2897	0.04078	0.14078	24.523	7.103	13
14	3.7975	0.2633	0.03575	0.13575	27.975	7.367	14
15	4.1772	0.2394	0.03147	0.13147	31.772	7.606	15
16	4.5950	0.2176	0.02782	0.12782	35.950	7.824	16
17	5.0545	0.1978	0.02466	0.12466	40.545	8.022	17
18	5.5599	0.1799	0.02193	0.12193	45.599	8.201	18
19	6.1159	0.1635	0.01955	0.11955	51.159	8.365	19
20	6.7275	0.1486	0.01746	0.11746	57.275	8.514	20
21	7.4002	0.1351	0.01562	0.11562	64.002	8.649	21
22	8.1403	0.1228	0.01401	0.11401	71.403	8.772	22
23	8.9543	0.1117	0.01257	0.11257	79.543	8.883	23
24	9.8497	0.1015	0.01130	0.11130	88.497	8.985	24
25	10.8347	0.0923	0.01017	0.11017	98.347	9.077	25
26	11.9182	0.0839	0.00916	0.10916	109.182	9.161	26
27	13.1100	0.0763	0.00826	0.10826	121.100	9.237	27
28	14.4210	0.0693	0.00745	0.10745	134.210	9.307	28
29	15.8631	0.0630	0.00673	0.10673	148.631	9.370	29
30	17.4494	0.0573	0.00608	0.10608	164.494	9.427	30
31	19.1943	0.0521	0.00550	0.10550	181.943	9.479	31
32	21.1138	0.0474	0.00497	0.10497	201.138	9.526	32
33	23.2252	0.0431	0.00450	0.10450	222.252	9.569	33
34	25.5477	0.0391	0.00407	0.10407	245.477	9.609	34
35	28.1024	0.0356	0.00369	0.10369	271 024	9.644	35
36	30.9127	0.0323	0.00334	0.10334	299.127	9.677	36
37	34.0039	0.0294	0.00303	0.10303	330.039	9.706	37
38	37.4043	0.0267	0.00275	0.10275	364.043	9.733	38
39	41.1448	0.0243	0.00249	0.10249	401.448	9.757	39
40	45.2593	0.0221	0.00226	0.10226	442.593	9.779	40

Interest table for life cycle costing—12% discount rate.

Factor:	SCA Single Compound Amount	PW Single Present Worth	USF Uniform Sinking Fund	PP Periodic Payment	UCA Uniform Compound Amount	PWA Present Worth Annuity	
Given:	P	F	F	P	A	A	
Find:	F	P	A	A	F	P	
n							n
1	1.1200	0.8929	1.00000	1.12000	1.000	0.893	1
2	1.2544	0.7972	0.47170	0.59170	2.120	1.690	2
3	1.4049	0.7118	0.29635	0.41635	3.374	2.402	3
4	1.5735	0.6355	0.20923	0.32923	4.779	3.037	4
5	1.7623	0.5674	0.15741	0.27741	6.353	3.605	5
6	1.9738	0.5066	0.12323	0.24323	8.115	4.111	6
7	2.2107	0.4523	0.09912	0.21912	10.089	4.564	7
8	2.4760	0.4039	0.08130	0.20130	12.300	4.968	8
9	2.7731	0.3606	0.06768	0.18768	14.776	5.328	9
10	3.1058	0.3220	0.05698	0.17698	17.549	5.650	10
11	3.4785	0.2875	0.04842	0.16842	20.655	5.938	11
12	3.8960	0.2567	0.04144	0.16144	24.133	6.194	12
13	4.3635	0.2292	0.03568	0.15568	28.029	6.424	13
14	4.8871	0.2046	0.03087	0.15087	32.393	6.628	14
15	5.4736	0.1827	0.02682	0.14682	37.280	6.811	15
16	6.1304	0.1631	0.02339	0.14339	42.753	6.974	16
17	6.8660	0.1456	0.02046	0.14046	48.884	7.120	17
18	7.6900	0.1300	0.01794	0.13794	55.750	7.250	18
19	8.6128	0.1161	0.01576	0.13576	63.440	7.366	19
20	9.6463	0.1037	0.01388	0.13388	72.052	7.469	20
21	10.8038	0.0926	0.01224	0.13224	81.699	7.562	21
22	12.1003	0.0826	0.01081	0.13081	92.503	7.645	22
23	13.5523	0.0738	0.00956	0.12956	104.603	7.718	23
24	15.1786	0.0659	0.00846	0.12846	118.155	7.784	24
25	17.0001	0.0588	0.00750	0.12750	133.334	7.843	25
26	19.0401	0.0525	0.00665	0.12665	150.334	7.896	26
27	21.3249	0.0469	0.00590	0.12590	169.374	7.943	27
28	23.8839	0.0419	0.00524	0.12524	190.699	7.984	28
29	26.7499	0.0374	0.00466	0.12466	214.583	8.022	29
30	29.9599	0.0334	0.00414	0.12414	241.333	8.055	30
31	33.5551	0.0298	0.00369	0.12369	271.293	8.085	31
32	37.5817	0.0266	0.00328	0.12328	304.848	8.112	32
33	42.0915	0.0238	0.00292	0.12292	342.429	8.135	33
34	47.1425	0.0212	0.00260	0.12260	384.521	8.157	34
35	52.7996	0.0189	0.00232	0.12232	431.663	8.176	35
36	59.1356	0.0169	0.00206	0.12206	484.463	8.192	36
37	66.2318	0.0151	0.00184	0.12184	543.599	8.208	37
38	74.1797	0.0135	0.00164	0.12164	609.831	8.221	38
39	83.0812	0.0120	0.00146	0.12146	684.010	8.233	39
40	93.0510	0.0107	0.00130	0.12130	767.091	8.244	40



LIST OF GOVERNMENT DEPARTMENTS

1. National Guards Presidency.
2. Presidency of Youth Welfare.
3. General Organization for Ports.
4. King Abdul Aziz City for Science and Technology.
5. Royal Commission for Jubail & Yanbue.
6. Ministry of Defence & Avaition (MODA).
7. Civil Avation.
8. Ministry of Interior.
9. Ministry of Municipal & Rural Affairs.
10. Municipality of Riyadh (Amanah).
11. Municipality of Jeddah (Amanah).
12. Municipality of Dammam (Amanah).
13. Municipality of Makkah (Amanah).
14. Municipality of Madinah (Amanah).
15. Riyadh Water Department.
16. Eastern Water Department.

17. Western Water Department.

18. Qaseem Water Department.

19. Assir Water Department.

20. Ministry of Public Works and Housing.

21. Ministry of Labour.

22. General Organization for Technical Education & Vocational Training.

23. Ministry of Health.

24. Ministry of Information.

25. Ministry of Education.

26. Presidency of Girl's Education.

27. Girl's College.

28. King Saud University.

29. King Abdul Aziz University.

30. King Fahd University of Petroleum & Minerals.

31. University of Al-emam Mohammed Bin Saud.

32. King Faisal University.

33. Um Al-qura University.

34. Islamic University.

35. Ministry of Communications.

36. Railroad Organization.

37. Ministry of Post, Telephone & Telegraph.

38. Ministry of Petroleum & Mineral Resources.

39. Ministry of Industry & Electricity.

40. Electricity Corporation.

41. Ministry of Agriculture & Water.

42. General Organization of Desalination.

43. Grain Silos & Flour Mills Organization.

44. Ministry of Pilgrims & Endowments.

45. Ministry of Finance & National Economy.

الرقم :
التاريخ : ١٤١٧/١/٥
توابع: استبانة (٩ صفحات)

السلام عليكم ورحمة الله وبركاته.

يقوم قسم هندسة وإدارة التشييد في كلية تصاميم البيئة بجامعة الملك فهد للبترول والمعادن بعمل بحث عن تطبيق دورة تكلفة الحياة في المشاريع إلا نشائية . تهدف هذه الدراسة الى التعرف على مدى تطبيق تكلفة دورة الحياة في المشاريع الإنشائية وإيجاد وتقييم المشاكل التي تعترض تطبيق هذا النظام .

الاستبيان المرفق بطيه يهدف الى استطلاع مرئيات مد راء الإدارات الحكومية المعنية بالتنفيذ أوالاشراف على المشاريع الانشائية العامة ومدراء المكاتب الهندسية التي تقوم بتقديم الخدمات الاستشارية للمشاريع الحكومية .

ستكون مقدرين تكرم سعادتكم بالاجابة على الاستبيان المرفق او احالته الى الجهة المعنية لديكم وموافاتنا بالاستبيان المكمل في أسرع وقت ممكن الى العنوان المذكور ادناه وبحد اقصى ١٥صفر ١٤١٧ هـ علما بأن تجاوبكم السريع سوف يكون محل تقديرلدينا وسيساهم في اتمام الدراسة .

نشكر لكم تعاونكم سلفا

د. سعدي عبدالعفوعساف
استاذمشارك
قسم هندسة وادارة التشييد
جامعة الملك فهد للبترول والمعادن
ص.ب : ٦٨٠
الظهران ٣١٢٦١

الإستبيـــان الخـــاص بالقطاعـــات الحكوميـة

الرجاء تزويدنا بالمعلومات التاليـة أن أمكن :

اسم الدائرة :

تليفون :

اسم المجيب :

التاريخ :

أولاً : التعريف بالمجيب

نرجو الإجابة على الأسئلة التالية وذلك بوضع علامة (✓) على الأختيار المناسب :-

١ - الرجاء ذكر المسمى الوظيفي :

أ - مهندس مشروع . ( )

ب - مهندس تكاليف . ( )

جـ - مهندس صيانة . ( )

د - مهندس تصاميم . ( )

هـ - أخرى ، فضلاً أذكرها :_____ ( )

٢ - الرجاء تحديد عدد سنوات الخبرة في المجال المذكور أعلاه :

أ - أقل من سنتين . ( )

ب - من ثلاث إلى خمس سنوات . ( )

جـ - من ست إلى عشر سنوات . ( )

د - أكثر من عشر سنوات . ( )

هـ - أخرى فضلاً أذكرها : _____ ( )

٣ – التأهيل للوظيفة جاء عن طريق :–

أ – الخبرة .

ب – درجة هندسية اذكرها : _____ ( )

جـ – درجة غير هندسية اذكرها : _____ ( )

د – تدريب على رأس العمل . ( )

هـ – أخرى ، فضلاً اذكرها : _____ ( )

ثانياً : تطبيق نظام تكلفة دورة الحياه :

الرجاء الإجابة على الأسئلة التالية وذلك بوضع علامة ( ) على الإختيار المناسب .

١ – هل لديك سابق معرفة بنظام تكلفة دورة الحياة ؟

أ – جيد جداً . ( )

ب – جيد . ( )

جـ – إلى حد ما . ( )

د – قليل . ( )

هـ – لا أدري . ( )

اذا كانت أجابتك على السؤال السابق هي (جـ ، د ، هـ) فالرجاء الرجوع الى الشرح الموجز في الملحق (A) قبل البدء في الإجابة على بقية الأسئلة .

٢ – هل يتم تطبيق نظام تكلفة دورة الحياة في دائرتكم ؟

أ – دائماً . ( )

ب – غالباً . ( )

جـ – أحياناً . ( )

د – نادراً . ( )

هـ – أبداً . ( )

٦ – ما هو الغرض الرئيسي من إستخدام نظام تكلفة دورة الحياة من دائرتكم ؟

أ – كجزء من برنامج الهندسة القيمية (value Engineering) ( )

ب – كطريقة مساعدة لتقييم خيارات عدة . ( )

جـ – كطريقة لتقدير تكاليف التشغيل (running cost) ( )

د – كطريقة لتقدير ميزانية النفقات . ( )

هـ – أخرى ، فضلاً اذكرها : _____ ( )

٧ – الرجاء ذكر نوع البيانات المستخدمة في حساب تكلفة دورة الحياة لكل جزء من أجزاء تكلفة دورة الحياه المذكورة في الجدول المرفق بوضع علامة (✓) في المكان المناسب .

مكونات تكلفة دورة الحياة	بيانات مصنعين أو موزعين	الحسابات التقديرية	الخبرة	بيانات السجلات السابقة	أخرى ، حددها
التكلفة الإبتدائية (Initial Cost)					
تكلفة الصيانة (Maintenace cost)					
تكلفة التشغيل (Running cost)					
تكلفة التجديد (Replacement cost)					
معدل الفائدة (Interest rate)					
طول الحياة الإقتصادية (Economic Life cycle)					
قيمة التخلص (Salvage Value)					

٨ – حجم الطاقم الذي يقوم بأداء نظام تكلفة دورة الحياة في دائرتكم ؟

أ – لا يوجد . ( )

ب – يوجد ١ فقط . ( )

جـ – من أثنين إلى خمسة . ( )

د – من ستة إلى عشرة . ( )

هـ – أكثر من عشرة ، فضلاً أذكرها : _____ ( )

٣ – أي من طرق التحليل الإقتصادي التالية يتم تطبيقه في دائرتكم في تقييم الخيارات المختلفة في مجالات التصميم ، التشييد أو الصيانة .

أ – القيمة المساوية (Present worth) . ( )

ب – التكلفة السنوية المساوية (Equivalent Anualised cost) . ( )

جـ – معدل العائد على الأصول (Rate of return) . ( )

د – معدل فترة الأسترداد (Pay back period) . ( )

هـ – معدل فترة الأسترداد الحاضر (Discounted pay - back period) . ( )

و – أخرى ، فضلاً اذكرها . _____

اذا كانت دائرتكم تقوم بتطبيق نظام تكلفة دورة الحياه فالرجاء الإجابة على جميع الأسئلة وفي حالة أنكم لا تقومون بتطبيق نظام تكلفة دورة الحياة في دائرتكم فيرجى التوقف إلى هذا الحد شاكرين لكم التكرم بالإجابة على هذا الجزء من الإستبيان .

٤ – من وجهة نظرك إلى أي مدى يتم تطبيق نظام تكلفة دورة الحياة في دائرتكم ؟

أ – يتم تطبيق النظام بالكامل . ( )

ب – يتم تطبيق ٨٠٪ فقط من النظام . ( )

جـ – يتم تطبيق ٦٠٪ فقط من النظام . ( )

د – يتم تطبيق ٤٠٪ فقط من النظام . ( )

هـ – يتم تطبيق ٢٠٪ فقط من النظام . ( )

٥ – متى بدأت دائرتكم بإدخال نظام تكلفة دورة الحياه ؟

أ – أقل من سنتين . ( )

ب – من ثلاث إلى خمس سنوات . ( )

جـ – من ست إلى عشر سنوات . ( )

د – أكثر من عشر سنوات . ( )

هـ – أخرى ، فضلاً اذكرها . _____

٩ – من المتوقع أن يتم التوسع في إستخدام نظام تكلفة دورة الحياة في دائرتكم .

أ – أوافق بشده . ( )

ب – أوافق . ( )

جـ – أوافق إلى حد ما . ( )

د – لا أوافق . ( )

هـ – لا أدري . ( )

١٠ – يتم تطبيق نظام تكلفة دورة الحياه في دائرتكم عن طريق :

أ – موظفين من نفس الإدارة . ( )

ب – استشارات هندسة خارجية . ( )

جـ – كلاً من أ ، ب . ( )

د – أخرى ، فضلاً اذكرها : _____ ( )

١١ – من وجهة نظرك إلى أي فئة من المشاريع المذكورة أدناه يلزم إدخال نظام تكلفة دورة الحياة في دراستها ؟

أ – جميع المشاريع الإنشائية ، بإغفال الحجم أو التكلفة . ( )

ب – جميع المشاريع التي تجاوزت تكلفتها ٥ ملايين ريال . ( )

جـ – جميع المشاريع التي تجاوزت تكلفتها ١٠ ملايين ريال . ( )

د – جميع المشاريع التي تجاوزت تكلفتها ٢٥ مليون ريال . ( )

هـ – جميع المشاريع التي تشمل على تكلفة عالية في الصيانة أو التشغيل . ( )

و – أخرى ، فضلاً اذكرها : _____ ( )

ملحق(٨)
دورة تكلفة الحياة

تعرف تكلفة دورة الحياة بانها التقييم الاقتصادي لمبنى أو جزء منه , أو نظام مع الاخذ بالاعتبار كافة التكاليف المهمه على مدى حياة المبنى أو المشروع ويكون التقديرالتكاليف بايجاد القيمة المساوية في الوقت الحاضر فعند المقارنة بين شخصين حيث يمتلك الاول ١٠٠ريال نقدا"والآخر يمتلك المبلغ علىاقترات تقدر بـ ١٠أشهرفعند المقارنة لابد من اعتبار القوة الشرائية لكل من القيمتين وذلك بايجاد القيمة المساوية لكلا المبلغين في الوقت الحاضر.

ويعنى بـ " التكاليف المهمة في تكلفة دورة الحياة" : جميع التكاليف المدرجة في الرسم (١) وهي تشمل على
الآتي :

التكلفة الأبتدائية : وتشمل على تكلفة التملك التي ترافق انشاء المبنى كقيمة الآرض وتكلفة البناء.

التكلفة التشغيلية : و تشمل المصروفات التي تنفق في تشغيل المبنى كقيمة الوقود ورواتب موظفي التشغيل .

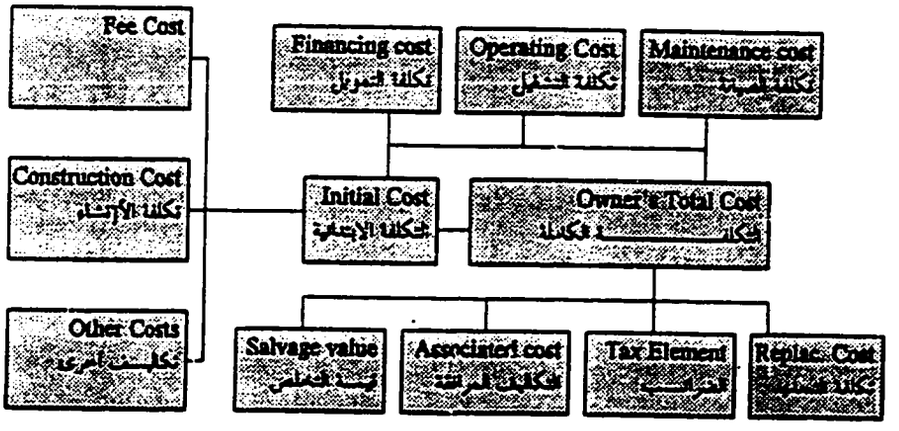
تكلفة الصيانة : وتشمل التكلفة الدورية للصيانة كمصروفات موظفي الصيانة.

تكلفة التجديد : وتشمل التكلفة التي تدفع لتغيير وظيفة المبنى كتغيير مبنى اداري الى حكومي .

تكلفة الضرائب : وتشمل التكلفة المتعلقة بالضرائب والقروض .

قيمة التخلص : وهي القيمة المساوية للمبنى أو جزء منه في نهاية دورة الحياة .

ويتم ايجاد قيمة كل من هذه التكاليف بناءا" على فرضيات ،خبرات أو استنتاجات من بيانات سابقة .وبذلك يكون التقييم قد شمل جميع التكاليف المهمة وليست فقط التكلفة الآبتدائية .



الرسم رقم (١)

مصطلحات مهمة

القيمةالحالية (Present Worth) : وهي طريقة اقيصادية تتطلب تحويل كافـــــة التكاليف الى القيمة الحالية وذلك يتم عن طريق تخفيض الحركة النقدية الى وقت واحد معين.

معدل فترة الاسترداد (Pay Back Period) :و هي الوقت اللازم لتحصيـــل التكـــاليف الناتجة عن التعديل أو التغيير.

معدل فترة الاسترداد الحاضر (Discounted-Pay Back Period) : وهي نفس معدل فترة الاسترداد (Pay Back Period) مع الأخذ في الأعتبار قيمة الوقت المادية.

الهندسة القيمية(Value Engineering):وهي طريقة تعتمد الأعتبار الوظيفي، ويشترك فيها عدة فرق من جهات مختلفة وتهدف الى تخفيض تكلفة دورة الحياة وتكلفة التشغيل .

دورة تكلفة الحياة الاقتصادية (Economic Life Cycle Cost) : وهي عملية التقدير الاقتصادي لجزء ، نظام أو مشـــروع يكون مقترحا في عدة تصاميم مختلفة . ويكون التقدير اعتمادا على كافة تكاليف التملك على امتداد فترة حياة المشروع. ويعبر عن ذلك بالقيمة المـــاوية بالدولار.

قيمة التخلص (Salvage Value) :وهي القيمة المقدرة للأصـــول في نهاية دورة حيـــاة المشروع.

علاقة التصميم الى التكلفة (Design to Cost) :وهي النســـبة التي يتمكن المصمم فيها من معرفة نسبة التوفيـــر الأكبر لأي من أجزاء المبنى على امتداد فترة حياة المشروع.

القيمة الســـنوية (الحولية):وهي طريقة اقتصادية يتم بموجبها تحويل جميع التكاليف الحاضرة والمستقبلية الى تكاليف موزعة على فترات زمنية منتظمة.

المثال التالي يوضح مفهوم تكلفة دورة الحياة :

نفترض ان هناك خيارين لتركيب وحدات تكيف معلقة(Air conditioning Rooftop) وذلك بالتكاليف المبينة في الجدول(١) ادناه :

نوع التكلفة	الخيـــــار الأول	الخيـــــار الثاني
التكلفة الأبتدائية	١٥٠٠٠	١٠٠٠٠
الطاقـه(التكلفة السنوية)	١٨٠٠	٢٢٠٠
الصيانة (التكلفة السنوية)	٥٠٠	٨٠٠
طول فترة الحياة	١٢سنة	٨سنوات

عند القيام بعمل حسابات مطولة لحساب تكلفة دورة الحياة لكل من الخيارين و ذلك بتحويل كافة التكاليف السنوية(Annual Costs)والتكاليف المتكررة(Recurring Costs) الى القيمة المساوية في الوقت الحالي يتضح الاتي كما هو موضح في الجدول (٢) :

نوع التكـــــلفة	الخيـــــار الأول	الخيـــــارالثاني
مجموع القيمة المساويةالحالية لتكاليف دورة الحياة	٤٣٤٧٣	٤٧٤٩٩ .

مجموع القيمة المساويةالحالية لتكاليف دورة الحياة = مجموع التكاليف المذكورة في الجدول رقم (١) عند تحويلها الى القيمة المساوية في الوقت الحاضر.

من الجدول السابق يتضح أنة بحساب تكلفة دورة الحياة يتضح أن الخيار الاول هو الخيار الاقل اذا فهو الخيار الأفضل مع أن الأختيار الثاني هو الخيـــــار الأقل في التكلفة الأبتدائية.

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
COLLEGE OF ENVIRONMENTAL DESIGN
Dept. of Construction Engineering & Management

وزارة التعليم العالي
جامعة الملك فهد للبترول و المعادن
كلية تصاميم البيئة
قسم هندسة وإدارة التشييد

Date : May /22/1996
No. : CEM/470

Dear Consulting Office Manager,

The Construction Engineering & Management Department, of the College of Environmental Design at King Fahd University of Petroleum and Minerals is presently researching applications of Life Cycle Costing in Construction Projects. The purpose of this study is to determine the extent of Life Cycle Costing applications in Construction Projects and identify and evaluate problems, faced in applying the concept.

The attached Questionnaire is designed to obtain the views and data from Managers of Government Agencies who have the authority to request and /or supervise the execution of Public Construction Projects and Managers of Consulting Offices who provide technical services to Government Agencies.

We will be grateful if you will answer the attached Questionnaire yourself, or request the concerned Department or Agency to do the same. Upon completion the Questionnaire may kindly be posted in the stamped self addressed envelope not later than July 04,1996. Your immediate action will be highly appreciated.

We promise that any data, material or opinion that will be given to us will be held in strict confidence and used for research purpose only.

We look forward to your cooperation.

Thank you

Dr. Sadi A. Assaf,
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CONSULTING FIRMS
QUESTIONNAIRE

Please , provide following personal information (optional) :

Firm name : _____

Telephone : _____

Answered by : _____

Date : _____

Part I : Respondents Description

Please answer the followings question. Indicate with a tick(✓) against the option :

1. Please indicate your job title :

a) Project engineer. ☐

b) Cost estimator. ☐

c) Maintenance engineer. ☐

d) Design engineer . ☐

e) Others , please specify _____ ☐

2) Indicate years of experience in field mentioned above :

a) Experience from 0 - 2 years. ☐

b) Experience from 3 - 5 years . ☐

c) Experience from 6 - 10 years. ☐

d) Experience more than 10 years ☐

e) Others , please specify _____ ☐

3) Your qualification was gained mainly through :

a) Experience , specify _____ . ☐

b) Engineering degree , specify _____. ☐

c) None academic degree, specify _____. ☐

d) On-job Training . ☐

e) Others , specify _____. ☐

Part II : Life Cycle Cost Application

Please circle or indicate with a tick (✓) the appropriate response:

1). Number of employees in your firm:

a. Less than 10 ☐
b. 11-30 ☐
c. 30 - 50 ☐
d. Over 50, please specify _____ . ☐

2). Do you know the concept of Life Cycle Costing?

a. Very well ☐
b. Well ☐
c. Somehow ☐
d. Little ☐
e. None ☐

If your answer to the above question is (c) , (d) or (e) , please refer to Appendix A of questionnaire for explanation of LCC before proceeding to the rest of the questions.

3). Is Life Cycle Costing presently applied in your firm?

a. Always ☐
b. Often ☐
c. Sometimes ☐
d. Little ☐
e. Never ☐

4). Which economic analysis methods are presently being used at your firm to evaluate different alternatives for design , construction and maintenance projects:

a. Present worth (PW) ☐
b. Equivalent annualized cost (EUAC) ☐
c. Rate of return (ROR) ☐
d Pay back method ☐
e. Discounted pay back ☐
f. Others ,specify_____ ☐

If Life Cycle Costing is presently applied in this organization please answer all the questions, if not you can stop at this point and we thank you for your cooperation

5). In your opinion , to what extent is Life Cycle Costing being applied at your firm?

a. LCC is being applied completely . ☐
b. LCC is being applied to 80% of projects. ☐
c. LCC is being applied to 60% of projects. ☐
d. LCC is being applied to 40% of projects. ☐
e. LCC is being applied to 20% of projects. ☐

6). When did you start the application of Life Cycle Costing?

a. 0-2 years ago. ☐
b. 3-5 years ago. ☐
c. 6- 10 years ago. ☐
d. More than 10 years ago. ☐
e. Others, please specify _____. ☐

7). For what purpose does your firm utilize Life Cycle Costing?:

a. As part of V.E (value engineering) program. ☐

b. As a technique helping to choose between alternatives. ☐

c. As a means for predicting future running cost ☐

d. As a means for budgeting for future expenditures. ☐

e. Others , please specify_____ . ☐

8). Please check which component of LCC as a source of information is (are) used for LCC calculation at your firm :

Components of LCC	Manufacturers specialist or suppliers	Predictive calculation	Experience	Historical Data	Others, specify
Initial cost					
Maintenance cost					
Operating cost					
Replacement cost					
Interest rate					
Economic life time					
Salvage value					

9). The size of Life Cycle Costing staff in this firm is:

a. None ☐
b. One ☐
c. 2 - 5 ☐
d. 6 - 10 ☐
e. Greater than 10, specify _____ . ☐

10). Life Cycle Costing is expected to expand in this firm :

a. Strongly agree ☐
b. Agree ☐
c. Somewhat agree ☐
d. Do not agree ☐
e. Do not know ☐

11). In your opinion , in which category of public projects should Life Cycle Cost be enforced ?:

a. All construction projects, regardless of size and cost ☐
b. Construction projects over 5 million Saudi Riyals ☐
c. Construction projects over 15 million Saudi Riyals ☐
d. Construction projects over 50 millions Saudi Riyals ☐
e. Construction projects that have high operating and maintenance cost. ☐
f. Others, please specify _____ . ☐

Part III : Problems in Application of Life Cycle Cost

Please rate the severity (effect) of the problems of application of Life Cycle Costing in your firm. If some problems are not mentioned , please add them and rate.

No	*The Problems*	*Very Severe*	*Severe*	*Some what severe*	*Some what not severe*	*Not Severe*
	Unfamiliarity Problems					
1	Un-familiarization of design-to-cost concept					
2	Lack of Knowledge of the concept					
3	Unknown relation between initial cost and running cost					
4	Unavailability of satisfactory references					
	Data Problems					
5	Unavailability of capital cost data					
6	Unavailability of maintenance data					
7	Unavailability of operation data					
8	Unavailability of interest rate data					
9	Unavailability of life time data					
10	Large volume of data needed					
11	Unavailability of standard method for collecting and recording of data					
12	Unavailability of data base management system					
	LCC Proccdure Problems					
13	Unreliability of decision taken					
14	Lack of integrity of forecasting					
15	Majority of LCC calculations involve uncertainty					
16	Unavailability of qualified staff					
17	Unavailability of qualified consultants					

No.	***Management Problems***	*Very severe*	*Severe*	*Somewhat severe*	*Somewhat not severe*	*Not severe*
18	Un-acceptance of the concept					
19	Government non-enforcement of LCC					
20	Client pressure to meet the capital budget limit					
21	Client pressure to meet time deadline on design					
22	Unclear benefits of LCC to Client					
23	Improper planning and control of management tasks at different LCC stages					
	Cost Problems					
24	Cost to be paid to designer to conduct LCC					
25	Cost to be paid for collecting and analyzing of data					
26	Difficulties in identifying cost components					

13. If you have any additional comments, please feel free to add them below:

_____

_____

_____

_____

Thank you for your cooperation.

Appendix A
(of questionnaire)

Life Cycle Costing:

It is defined as an economic assessment of an item , area , system or facility considering all significant costs of ownership over its economic life , expressed in terms of equivalent dollars or riyals. A significant key to LCC is the time value of money. Assume that one person has 100 SR in the hand , another has 100 SR promised to be paid 10 years from now and a third is collecting 10SR a month for 10 months. Each one of these , has assets of 100SR . It is not easy to say that all the assets are equal interms of today's purchasing power because the assets are spread across different points in time . Their money has to brought back to baseline (reference time) to ,make fair comparison between costs.

The LCC definition states that all " Significant costs of ownership" should be included as shown in *attached figure on next page* which illustrates the types of cost that may be considered significant by the designer and client for LCC study .

Initial Costs include the owner's cost associated with initial development of facility including project costs (fees , real states, sites and so on) as well as construction cost.

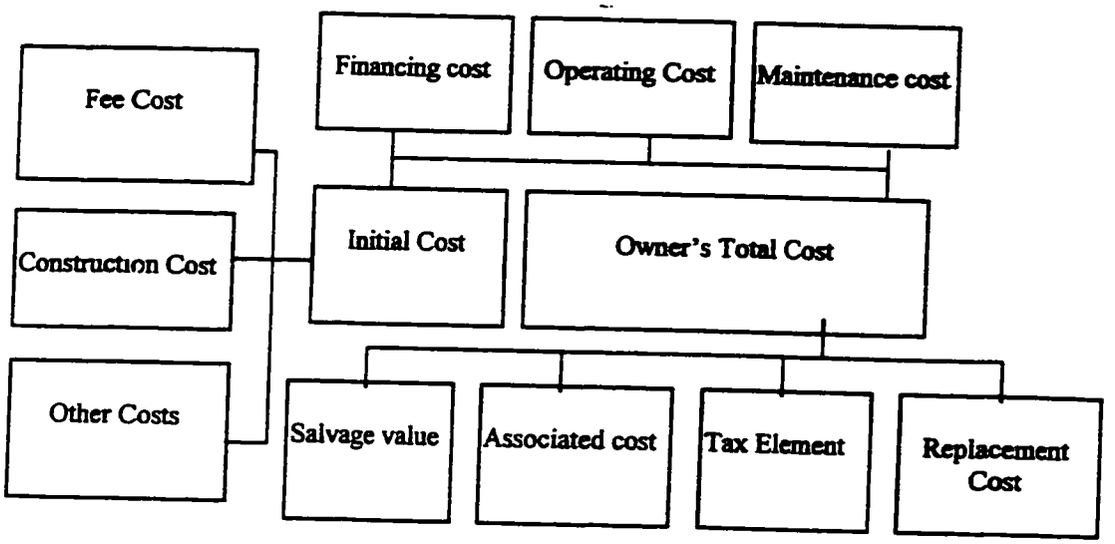
The operation (including energy) cost is used to keep track of such item as fuel and salaries required to operate the facility .

The maintenance costs include costs of regular custodial care and repair, annual maintenance contracts and salaries of facility staff performing maintenance tasks.

Alteration costs are those involved in changing the function of space. For example if you plan to change the second floor of your building to an apartment instead of, a show room, there will be the cost of conversion.

The replacement cost would be one time cost to be incurred in the future to maintain the original function of facility or an item .***Tax elements*** include assigned costs associated with taxes, credits and depreciation.

The associated costs include other identifiable cost not covered previously associated with a facility decision and may include function use , security and insurance ***Salvage value*** is the value of competing alternatives at the end of the life cycle period.



Definitions of Terms :

EUAC: Economic method that requires conversion of all present and future expenditures to a uniform annual cost.

Non-recurring Costs : Costs that occur or are expected to occur once through the life of the project .

Pay Back (PB) period : The time it takes the savings resulting from a modification to pay back costs involved

Present Worth (PW) : Economic method that requires conversion of all present and future expenditures to a base line of today's cost .

Recurring Costs : Costs that occur on a periodic basis through the life of the project .

Value engineering : A creative organized approach whose objective is to optimize the life cycle cost and performance facility .

Discount interest rate : The minimum acceptable rate of return for client for investment purposes of borrowing rate of interest .

Alternatives : The different choices or methods by which objectives may be attained.

Reference

1- Ahmed, Nazim U, "A design and Implementation Model of LCC Management System" , *Information and management* , V. 28, p261-265 , 1995.

2- Al-Hazmi, M. "Causes of Delay In Large Building Construction Projects " MS Thesis, King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia,1987.

3- Air Force Material Command (AFMC) , *Acquisition Logistic Management Air Force Material Command* , Wright-Patterson AFB OH , January 1995.

4- Al-Hudaif, S. "Value Engineering In Operation and Maintenance Projects", *Value News Letter*, V. 01, No. 3, p2 , Nov., 1995.

5- Al-Jarallah, M. "Construction Industry in Saudi Arabia", *Journal of Construction Engineering and Management*, V. 109, No. 4, pp. 355-358, Dec. 1983.

6- Al-Salmi , Hamoud A , Interview , Ministry of Municipal and Rural Affairs , Riyadh , 1996.

7- Al-Sugheir M.A , " The Application of Value Engineering in Public Construction Projects in Saudi Arabia " , MS thesis , King Fahd University of Petroleum and Minerals (KFUPM) , June 1987.

8- " Life Cycle Analysis: A Guide for Architects ", *American Institute of Architects (AIA),* Washington, 1977.

9- "Measuring Life Cycle Costing of Building and Building Systems". *American Society for Testing and Materials (ASTM),* ASTM 917-89, Philadelphia, ASTM, 1990.

10- Ashworth, Allan and Au-Yeung, Peter, "Evaluation of Life Cycle Costing as a Practical Tool During Building Design", *Fourth International Symposium on Building Economics,* Cφenhagen ,1987.

11- Assaf, A., *Engineering Economics Notes*, ARE 522, 1994

12- Bishop, Donald," Some Reflections of Life Cycle Costing ", The Bartlett School of Architecture and Planning, University College, London, 1984.

13- Brandon, Peter S., " Quantity Surveying Techniques", Oxford, London, 1992.

14- Brown, Robert J., and Rudolph Yanuck, R., " Introduction to Life Cycle Costing", Atlanta, Georgia, The Fairmont Press, Inc., 1985.

15- *Building Owners and Managers Association International (BOMA),* BOMA Experience Exchange Report, New York, 1990.

16- Coullahan , Richard and Charles, Siegfried , CPE , " Facilities Maintenance Using Life Cycle Asset Management " , *Facilities Engineering Journal* , May/April ,1996.

17- Defense Systems Management College , *System Engineering Management Guide* , Ft Belvoir VA :DSMC , January 1990.

18- Dell'Isola Alphonse J. , *Course on Life Cycle Costing* , Riyadh, Oct 17-18,1995.

19- Dell'Isola, Alphonse, J., and Stephen Kirk J., *Life Cycle Cost Data* , New York, McGraw-Hill Book Company, 1983.

20- Dell'Isola, Alphonse, J., and Stephen Kirk J., *Life Cycle Costing Design Professionals* , New York, McGraw-Hill Book Company, 1995.

21- Flanagan, R., Norman, G. and J. David Furbur , "Life Cycle Costing for Construction ", London , *Surveyor Publications* , 1983 .

22- Flanagan, R., Norman, G., Meading, J. and Robinson, G., *Life Cycle Costing Theory and Practice* , Oxford, London, BSP Professional Books, 1989.

23- Flanagan Roger ,"Life Cycle Costing: A means for Evaluating Quality", University of Reading, Surveyors Publications Ltd, 1983.

24- Gage , Douglas C. et. al , *Operating and Support, Cost Estimating : A Primer* (Revised Edition) , Acquisition Logistic Concept and Analysis Division , Acquisition Logistics Directorate , Aeronautical System Center , Wright- Patterson AFB OH , Oct.1994.

25- Gess, David, "Life Cycle Cost Management", *Perspectives*, Autumn 1994.

26- Kabbani, Isam A , Interview , Riyadh , 1996.

27- Kabbani, Isam Ali, "Applying Life Cycle Costing in Building Design", *The Fourth Saudi Engineering Conference*, Jeddah, Vol. 1, pp.189-196, 1995

28- Macedo, Manual C. Jr. , Paul Dobrow V, and O'Rourke, Joseph J., *Value Management for Construction* , New York, John Viley and Sons, Inc., 1978.

29- Mahmoud , Magdy Ahmad, "Floor Finishing Materials and Systems: An Expert System for Evaluation and Selection", MS thesis, King Fahd Uni - versity of Petroleum and Minerals(KFUPM),1993.

30- McDermott F., V.B Torrance and P.G Cheesman, " Forecasting Life span for Life Cycle Costing", *Fourth International Symposium on Building Economics*, Copenhagen 1987.

31- Ministry of Planning, *Fifth Development Plan* , Riyadh,1990

32- Ministry of Planning, *Sixth Development Plan* , Riyadh,1995 .

33- Neely, Edgar S. , Neatherman, R. D., and James R. Strim , " Maintenance Resource Prediction in the Facility Life Cycle Cost Process" , *US Army Corps of Engineers* , May 1991.

34- Pfaffenberger, R., and Patterson, J., *Statistical methods for business and economics* , Richard D. Irwin, Inc., Homewood, III., 1977.

35- Picken , David H , "Life Cycle Costing : Can it be effective", *Fourth Symposium of Building Economics*, Copenhagen ,1987.

36- Preiser , Wolfgang F.E , *Building Evaluation*, Plenum Press, New York, 1989.

37- Querns, Wesly R., " A Way to Handle Energy Costs in Value Engineering", *Cost Engineering*, Vol., 36 No.11, pp18-21, Nov. 1994.

38- Rose, Aaron, "Life Cycle Costing Today", *American Association of Cost Engineers*, pp. J3.1 - J3.4,1984

39- U. S. General Services Administration (USGSA) , Public Building Services , *Value Management* , Oct. ,1978.

40- Ward, Robertson, " Office Building Systems Performance and Functional Analysis", *Fourth International Symposium on Building Economics*, Copenhagen 1987

41- Wuebbenhorst , Klaus L., "Life Cycle Costs in the West Germany Construction Industry", *Transaction of the American Association of Cost Engineers*, pp.24-27, June, 1984.